

Heterogeneous Agent Trade

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[@tradewartracker](#)

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What am I doing?

Big picture — these are the questions that interest me...

1. What are distributional consequences of trade?
2. Is there a role for trade policy to improve outcomes?

One mechanism behind 1. is heterogeneity in expenditure shares on traded goods and **elasticities**.

- [Auer, Burstein, Lein, and Vogel \(2022\)](#) is a nice example. In the context of the 2015 Swiss appreciation, they find that poor households are more price elastic.

Behind 2. are inefficiencies arising from market incompleteness that feed into product markets... so lack of insurance against life's circumstances distorts the pattern of trade.

This paper:

GE, heterogeneous agent model of trade delivering ABLV-like facts. I work out the implications for aggregate trade, the gains from trade, and the normative implications.

How I do it...

Two ingredients:

- Trade as in Armington, but households have random utility over varieties — [McFadden \(1974\)](#)
- Standard incomplete markets model with households facing incomplete insurance against idiosyncratic productivity and taste shocks — [Bewley \(1979\)](#)

Qualitatively I characterize...

- How price elasticities vary at the micro-level and when micro-heterogeneity shapes aggregates.
- The welfare gains from trade at the micro and macro level.
- The efficient allocation and, thus, how market incompleteness shapes these outcomes.

Quantitatively, I compute a 19 country model (the [Eaton and Kortum \(2002\)](#) data) and... today, gains from trade and the role of the asset market, and a little bit about the planner.

Model: Production and Trade

M countries. Each country produces a nationally differentiated product as in Armington.

In country i , competitive firms' produce variety i with:

$$Q_i = A_i N_i,$$

where A_i is TFP; N_i are efficiency units of labor supplied by households.

Cross-country trade faces obstacles:

- iceberg trade costs $d_{ij} > 1$ for one unit from supplier j to go to buyer i .

This structure leads to the following prices that households face

$$p_{ij} = \frac{d_{ij} w_j}{A_j}.$$

Model: Households I

Continuum of households $k \in [0, L_i]$ in each country i . Household preferences:

$$\mathbb{E} \sum_{t=0}^{\infty} \beta^t \tilde{u}_{ijt}^k$$

where conditional direct utility for good j is

$$\tilde{u}_{ijt}^k = u(c_{ijt}^k) + \epsilon_{jt}^k, \quad j = 1, \dots, M$$

Assumptions:

- discrete-continuous choice. . . so first chose one variety, then continuous choice over quantity.
- ϵ_{jt}^k s are iid across hh and time; distributed Type 1 Extreme Value with dispersion parameter σ_ϵ .
- For now, only that u is well behaved.

A generalization with multiple sectors is the “infinite shopping aisle” approach we use in [Mongey and Waugh \(2022\)](#).

Model: Households II

Household k 's efficiency units z_t evolve according to a Markov Chain. They face the wage per efficiency unit w_{it} .

Households borrow or accumulate a non-state contingent asset, a , with gross return R_i . Household's face the debt limit

$$a_{t+1} \geq -\phi_i.$$

Conditional on a variety choice, a household's budget constraint is

$$p_{ij}c_{ijt} + a_{t+1} \leq R_i a_t + w_{it}z_t.$$

What Households Do I

Focus on a stationary setting. A hh's state are its asset holdings a and shock z .

1. Condition on variety choice their problem is:

$$v_i(a, z, j) = \max_{a', c_{ij}} \left\{ u(c_{ij}) + \epsilon_j + \beta \mathbb{E}[v_i(a', z')] \right\}$$

$$\text{subject to } p_{ij}c_{ij} + a' \leq R_i a + w_i z \quad \text{and} \quad a' \geq -\phi_i.$$

2. The ex-post value function of a household in country i is

$$v_i(a, z) = \max_j \{ v_i(a, z, j) \}.$$

What Households Do II

Two equations characterizing the commodity choice, consumption / savings. . .

1. The choice probability is:

$$\pi_{ij}(a, z) = \exp\left(\frac{v_i(a, z, j)}{\sigma_\epsilon}\right) / \Phi_i(a, z)$$

$$\text{where } \Phi_i(a, z) := \sum_{j'} \exp\left(\frac{v_i(a, z, j')}{\sigma_\epsilon}\right)$$

2. Away from the constraint, consumption and asset choices must respect this Euler Equation:

$$\frac{u'(c_i(a, z, j))}{p_{ij}} = \beta R_i \mathbb{E}_{z'} \left[\sum_{j'} \pi_{ij'}(a', z') \frac{u'(c_i(a', z', j'))}{p_{ij'}} \right].$$

Aggregates arise from explicit aggregation of hh-level actions. Two examples:

1. Aggregate, bilateral imports and exports are

$$M_{ij} = L_i \int_z \int_a p_{ij} c_i(a, z, j) \pi_{ij}(a, z) \lambda_i(a, z), \quad X_{ji} = L_j \int_z \int_a p_{ji} c_j(a, z, i) \pi_{ji}(a, z) \lambda_j(a, z),$$

where λ_i is the *endogenous* distribution of hhs across states. Here trade flows take on a mixed-logit form similar to [Berry, Levinsohn, and Pakes \(1995\)](#).

2. The national income accounting identity ($GDP = C + I + G + X - M$) ...

$$p_i Y_i = \underbrace{L_i \sum_j \int_z \int_a p_{ij} c_i(a, z, j) \pi_{ij}(a, z) \lambda_i(a, z)}_{\bar{P}_i \bar{C}_i} + \underbrace{\left[\sum_{j \neq i} X_{ji} - \sum_{j \neq i} M_{ij} \right]}_{-R_i A_i + A'_i}.$$

The Decentralized Stationary Equilibrium. A Decentralized Stationary Equilibrium are asset policy functions and commodity choice probabilities $\{g_i(a, z, j), \pi_{ij}(a, z)\}_{ij}$, probability distributions $\{\lambda_i(a, z)\}_i$ and positive real numbers $\{w_i, p_{ij}, R_i\}_{ij}$ such that

- i Prices (w_i, p_{ij}) satisfy the firms problem;
- ii The policy functions and choice probabilities solve the household's optimization problem;
- iv The probability distribution $\lambda_i(a, z)$ induced by the policy functions, choice probabilities, and primitives satisfies the law of motion and is stationary;
- v Goods market clears:

$$p_i Y_i - \sum_j^M X_{ji} = 0, \quad \forall i$$

- v Bond market clears with either

$A'_i = 0, \quad \forall i$ in the case of financial autarky, or

$$\sum_i A'_i = 0, \text{ in the case of financial globalization and } R_i = R \quad \forall i$$

Proposition #1: The H-A Trade Elasticity. The trade elasticity between country i and country j is:

$$\theta_{ij} = 1 + \int_a \int_z \left\{ \theta_{ij}(a, z)^I + \theta_{ij}(a, z)^E \right\} \omega_{ij}(a, z) - \left\{ \theta_{ii}(a, z)^I + \theta_{ii}(a, z)^E \right\} \omega_{ii}(a, z),$$

which is the difference between ij and ii expenditure-weighted micro-level elasticities. The micro-level elasticities for households with states a, z are an intensive and extensive elasticity

$$\theta_{ij}(a, z)^I = \frac{\partial c_i(a, z, j)/c_i(a, z, j)}{\partial d_{ij}/d_{ij}}, \quad \theta_{ij}(a, z)^E = \frac{\partial \pi_{ij}(a, z)/\pi_{ij}(a, z)}{\partial d_{ij}/d_{ij}},$$

and $\omega_{ij}(a, z)$ are the expenditure weights.

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and $\omega_{ij}(a, z)$ are the expenditure weights.

$$\theta_{ij}(a, z)^I = \left[- \frac{\partial g_{ij}(a, z) / p_{ij} c_{ij}(a, z)}{\partial p_{ij} / p_{ij}} - 1 \right] \frac{\partial p_{ij} / p_{ij}}{\partial d_{ij} / d_{ij}}.$$

The idea here is that reduction in trade costs relaxes the hh's budget constraint and then the division of new resources between assets and expenditure determines the intensive margin elasticity.

The H-A Trade Elasticity

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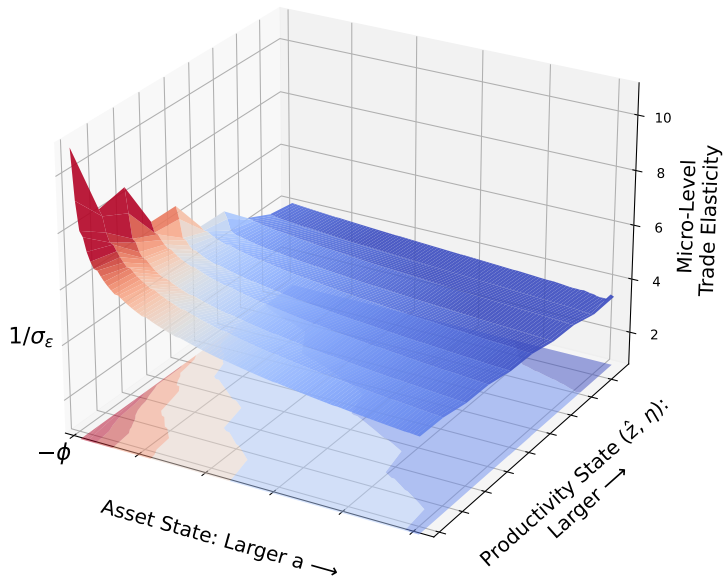
and $\omega_{ij}(a, z)$ are the expenditure weights.

$$\theta_{ij}(a, z)^E = -\frac{\partial \Phi_i(a, z) / \Phi_i(a, z)}{\partial d_{ij} / d_{ij}} + \frac{1}{\sigma_\epsilon} \frac{\partial v_i(a, z, j)}{\partial d_{ij} / d_{ij}}.$$

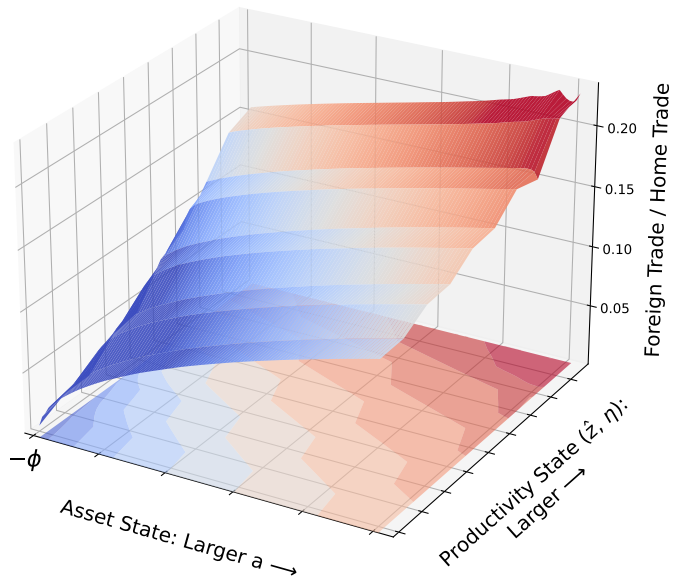
The interesting bit is $\frac{\partial v_i(a, z, j)}{\partial d_{ij} / d_{ij}} \dots$

In the paper, I show that if Arrow-Pratt measure of relative risk aversion > 1 than hh's with (i) high $u'(c)$ and (ii) high MPCs are more price elastic. **So poor hh's are the most price sensitive.**

Trade Elasticities by HH-Level State



Trade Shares: $M_i(a, z, j)/M_i(a, z, i)$, by HH-Level State



Proposition #2: H-A Welfare Gains from Trade. The gains from trade are

$$\frac{dW_i}{dd_{ij}/d_{ij}} \approx \int_z \int_a \left\{ \underbrace{\frac{dv_i(a, z)}{dd_{ij}/d_{ij}}}_{\text{gains to hh}} + \underbrace{v_i(a, z) \frac{d\lambda_i(a, z)/\lambda_i(a, z)}{dd_{ij}/d_{ij}}}_{\text{gains to reallocation}} \right\} L_i \lambda_i(a, z),$$

where v_i is value function before realization of taste shocks; \approx is about abstracting from transition.

Household-level gains are

$$\frac{dv_i(a, z)}{dd_{ij}/d_{ij}} \approx \sigma_\epsilon \frac{d\Phi_i(a, z)/\Phi_i(a, z)}{dd_{ij}/d_{ij}}$$

Just like [Eaton and Kortum \(2002\)](#)! It's all about how this price-index-like thing changes.

Proposition #2: H-A Welfare Gains from Trade. The gains from trade are

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where v_i is value function before realization of taste shocks; \approx is about abstracting from transition.

Household-level gains are

$$\frac{dv_i(a, z)}{dd_{ij}/d_{ij}} \approx \sum_j \pi_{ij}(a, z) \frac{dv_{ij}(a, z)}{dd_{ij}/d_{ij}}$$

The change in the $\Phi_i(a, z)$ thing (previous slide if you fell asleep) is share-weighted average of choice-specific value functions.

Next step... one algebra trick.

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Household-level gains are

$$\frac{dv_i(a, z)}{dd_{ij}/d_{ij}} \approx \underbrace{\sum_j \pi_{ij}(a, z) \left\{ \frac{dv_{ij}(a, z)}{dd_{ij}/d_{ij}} - \frac{dv_{ii}(a, z)}{dd_{ij}/d_{ij}} \right\}}_{\text{how relative valuations change}} + \frac{dv_{ii}(a, z)}{dd_{ij}/d_{ij}}$$

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$$\frac{dv_i(a, z)}{dd_{ij}/d_{ij}} \approx \underbrace{\sum_j \pi_{ij}(a, z) \left\{ \frac{dv_{ij}(a, z)}{dd_{ij}/d_{ij}} - \frac{dv_{ii}(a, z)}{dd_{ij}/d_{ij}} \right\}}_{= \text{how the home choice, } \pi_{ii}, \text{ changes}} + \frac{dv_{ii}(a, z)}{dd_{ij}/d_{ij}}$$

Now recursively iterate forward in time given how v_{ii} connects with v_i next period.

Proposition #2: H-A Welfare Gains from Trade. The gains from trade are

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where v_i is value function before realization of taste shocks; \approx is about abstracting from transition.

Household-level gains are

$$\frac{dv_i(a, z)}{dd_{ij}/d_{ij}} \approx \mathbb{E}_z \sum_{t=0}^{\infty} \beta^t \left\{ -\sigma_{\epsilon} \frac{d\pi_{ii}(a_t, z_t)/\pi_{ii}(a_t, z_t)}{dd_{ij}/d_{ij}} + u'(c_{ii}(a_t, z_t)) \left[a_t \frac{dR_i/p_{ii}}{dd_{ij}/d_{ij}} \right] \right\}.$$

HH-level gains pick up two effects:

- An ACR-like term summarizing how relative valuations across choices change.
- How hh's real wealth (+ or -) change through GE effects on prices — all evaluated at the hh's marginal utility of consumption.

Proposition #3: Separation of Trade and Micro-Heterogeneity. When preferences are logarithmic over the physical commodity, choice probabilities are independent of household heterogeneity

$$\pi_{ij}(a, z) = \exp\left(\frac{-\log p_{ij}}{\sigma_\epsilon}\right) \bigg/ \sum_{j'} \exp\left(\frac{-\log p_{ij'}}{\sigma_\epsilon}\right),$$

and the trade elasticity is

$$\theta = -\frac{1}{\sigma_\epsilon}.$$

And hh-level gains from trade

$$\frac{dv_i(a, z)}{dd_{ij}/d_{ij}} \approx \underbrace{-\frac{1}{\theta(1-\beta)} \times \frac{d\pi_{ii}/\pi_{ii}}{dd_{ij}/d_{ij}}}_{\text{ACR}} + \underbrace{\mathbb{E}_z \sum_{t=0}^{\infty} \beta^t \left[u'(c_{ij}(a_t, z_t)) a_t \frac{dR_i/p_{ij}}{dd_{ij}/d_{ij}} \right]}_{\text{In financial autarky (balanced trade) this} = 0}.$$

This mimics the results of [Anderson, De Palma, and Thisse \(1987\)](#). This was not obvious to me given the environment ... risk, market incompleteness, borrowing constraints, etc.

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And we are back to [Arkolakis et al. \(2012\)](#) + what's going on with the financial market.

Proposition #4: The Centralized (Efficient) Allocation. The allocation satisfying the Centralized Planning Problem (with a utilitarian SWF and country-specific Pareto weights ψ_i) is:

1. An allocation of consumption satisfying:

$$\psi_i u'(c_i(z, j, t)) = \chi_j(t) d_{ij}$$

where $\chi_j(t)$ is the multiplier on j resource constraint for variety j ,

2. And variety choice probabilities:

$$\pi_{ij}(t) = \exp\left(\frac{u(c_i(j, t)) - u'(c_i(j, t))c_i(j, t)}{\sigma_\epsilon}\right) / \sum_{j'} \exp\left(\frac{u(c_i(j', t)) - u'(c_i(j', t))c_i(j', t)}{\sigma_\epsilon}\right).$$

1. is a [Backus and Smith \(1993\)](#)-like condition.
2. is new — trade should reflect the net social benefit of buying that commodity.

Proposition #5: Trade Elasticities and Welfare Gains in the Efficient Allocation The trade elasticity between i, j in the efficient allocation is:

$$\theta_{ij} = -\frac{1}{\sigma_{\epsilon}} \left[u'(c_{ij}) c_{ij} \right].$$

And the welfare gains from a reduction in trade costs between i, j are

$$\frac{dW}{dd_{ij}/d_{ij}} = \frac{\partial W}{\partial d_{ij}/d_{ij}} = \frac{\psi_i}{1 - \beta} \times u'(c_{ij}) c_{ij} \pi_{ij} L_i,$$

which is the discounted, weighted, direct effect from relaxing the resource constraint.

Mimics the results of [Atkeson and Burstein \(2010\)](#) but with household (not firm) heterogeneity.

With log preferences the direct effect is equivalent to [Arkolakis et al. \(2012\)](#).

This is what I'll go over the next couple of slides. . .

1. Calibrate my model using my “gravity as a guide” approach on the 19 country data set of [Eaton and Kortum \(2002\)](#).
2. Some gains from trade results.
3. Trade in the efficient allocation vs. the decentralized allocation.

My Calibration Approach: Use Gravity as a Guide

The problem: no closed form map from trade flows to parameters as in static, trade models do. But I want the model to replicate the geographic pattern of activity seen in the data.

- Step 0. Impose a trade cost function to reduce the parameter space

$$\log d_{ij} = d_k + b + l + e_h + m_i$$

- Step 1. Run this gravity regression (same as in [Eaton and Kortum \(2002\)](#)) on the data

$$\log \left(\frac{M_{ij}}{M_{ii}} \right) = l m_i + E x_j + d_k + b + l + e_h + \delta_{ij}$$

- Step 2. Guess TFP terms and coefficients on the trade cost function, compute an equilibrium, run the same regression from above on model generated data.
- Step 3. Evaluate difference between model and data and update parameters until convergence.

My Calibration Approach: Use Gravity as a Guide

The solution: use the gravity regression “as a guide” where I estimate parameters of the model so that the regression coefficients run on my model's data match that seen in the data.

- Step 0. Impose a trade cost function to reduce the parameter space

$$\log d_{ij} = d_k + b + l + e_h + m_i$$

- Step 1. Run this gravity regression (same as in [Eaton and Kortum \(2002\)](#)) on the data

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- Step 3. Evaluate difference between model and data and update parameters until convergence.

Other Parameters

Parameters common across countries:

- CRRA for u with relative risk aversion = 1.5.
- Earnings process is a mixture of a persistent and transitory component and calibrated as in [Krueger, Mitman, and Perri \(2016\)](#).
- Discount factor β juggled to target a world interest rate of 1.5% in financial globalization case.

Parameters scaled across countries to deliver “balanced growth” like properties.

- Set $\sigma_{\epsilon,i} = \sigma_{\epsilon} \times A_i^{1-\gamma}$ and $\sigma_{\epsilon} = 0.25$.
In a log model corresponds with a trade elasticity of 4.
- I set the borrowing constraint so $\phi_i = \phi \times A_i$ where $\phi = 0.50$.
Interpretation is the constraint = 50 % of average, autarky labor income.

Bilateral Trade: Model vs. Data

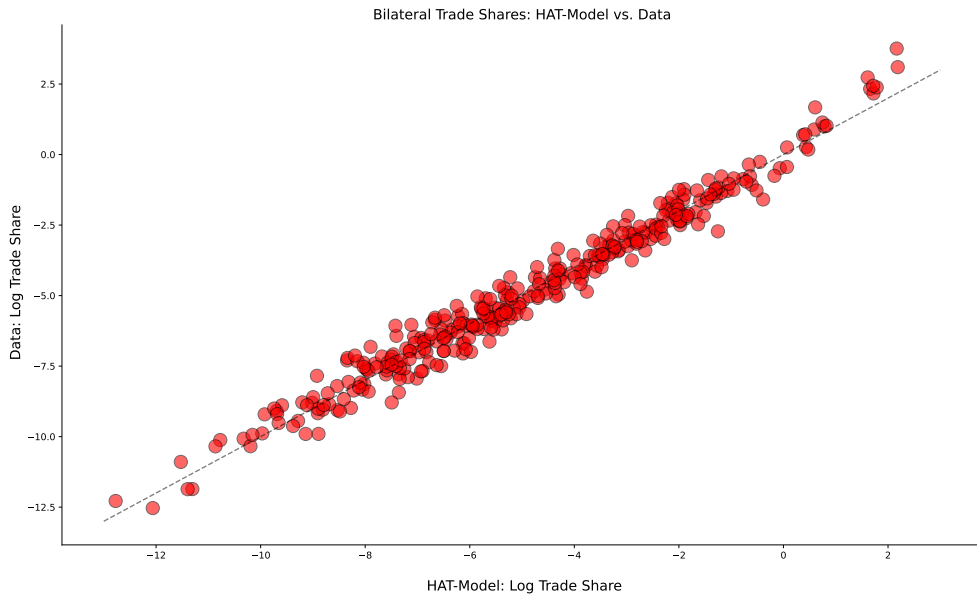


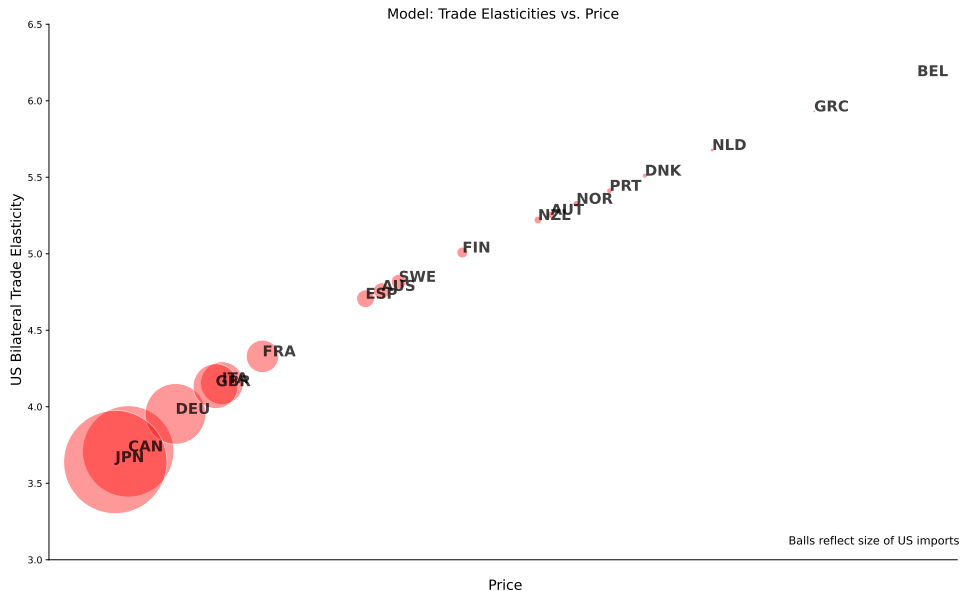
Table 1: Estimation Results

Barrier	Moment	HAT-Model	
		Model Fit	Parameter
[0, 375)	−3.10	−3.10	2.35
[375, 750)	−3.67	−3.67	2.81
[750, 1500)	−4.03	−4.03	3.09
[1500, 3000)	−4.22	−4.22	3.23
[3000, 6000)	−6.06	−6.06	4.88
[6000, maximum]	−6.56	−6.56	5.69
Shared border	0.30	0.30	0.91
Language	0.51	0.51	0.87
EFTA	0.04	0.04	0.98
European Community	0.54	0.54	0.89

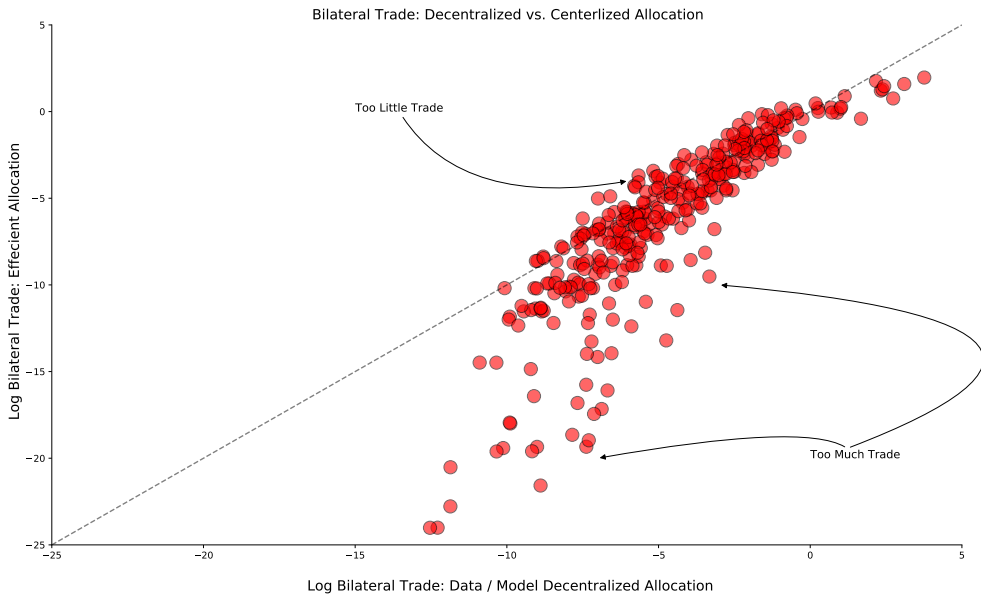
Note: The first column reports data moments the HAT-model targets. The second reports the model moments. The third column reports the estimated parameter values.

Far distances \approx 10 percent less expensive than standard models would predict.

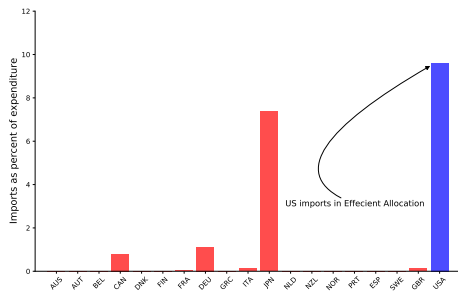
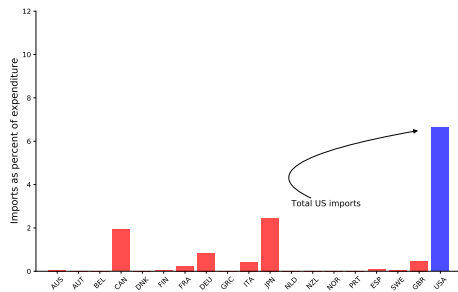
US Trade Elasticities: $-\theta_{us,j}$



Efficient Trade



US Imports: Decentralized vs. Efficient Allocation



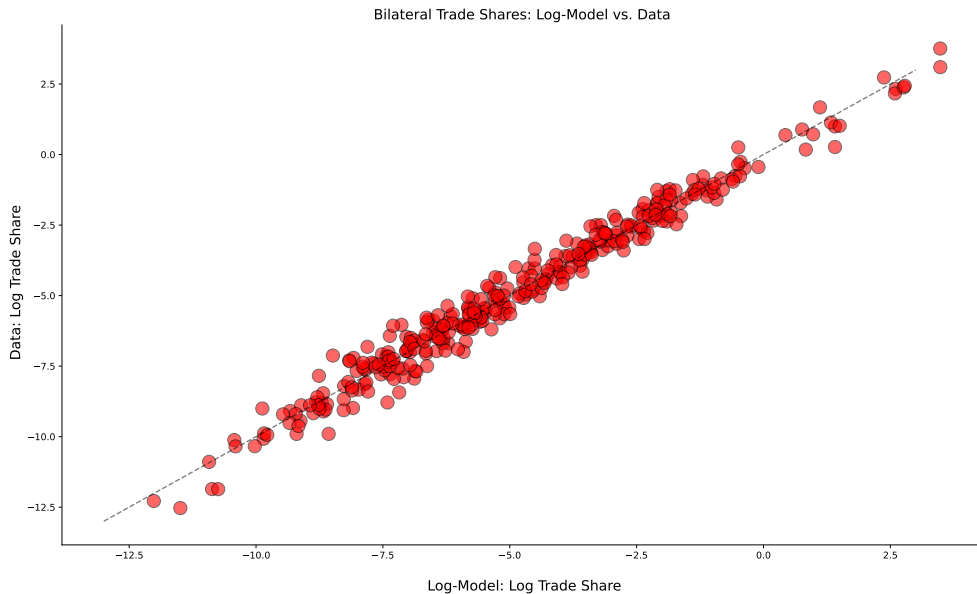
Where I'm headed next...

Lot's to do, but “big picture” this is where I'm aiming:

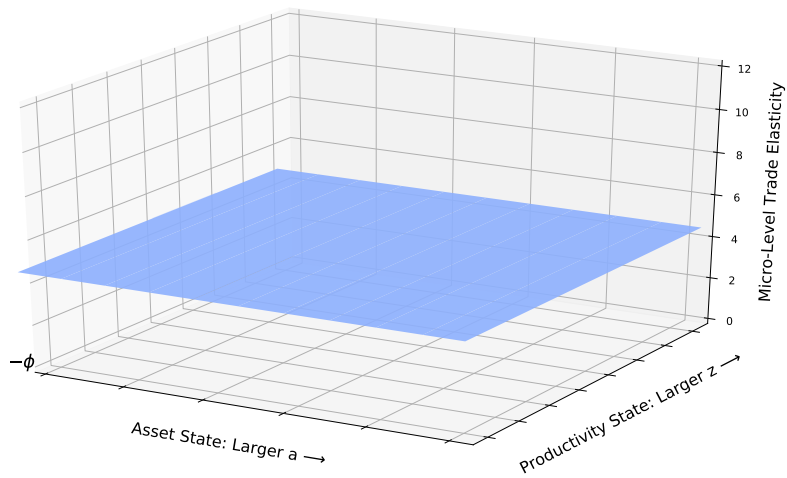
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Log Model — Fit of Trade Data



Log Model — Micro Elasticities



Micro-Elasticities I: The Intensive Margin

How do households respond on the **intensive** margin to a change in trade costs?

$$\begin{aligned}\theta_{ij}(a, z)' &:= \frac{\partial c_{ij}(a, z)/c_{ij}(a, z)}{\partial d_{ij}/d_{ij}}, \\ &= \left[- \frac{\partial g_{ij}(a, z)/p_{ij} c_{ij}(a, z)}{\partial p_{ij}/p_{ij}} - 1 \right] \frac{\partial p_{ij}/p_{ij}}{\partial d_{ij}/d_{ij}}.\end{aligned}$$

The idea: A reduction in trade costs relaxes the hh's budget constraint, so the intensive margin elasticity depends on the division of new resources between assets and expenditure.

Micro-Elasticities II: The Extensive Margin

How do households respond on the **extensive** margin?

$$\begin{aligned}\theta_{ij}(a, z)^E &:= \frac{\partial \pi_{ij}(a, z) / \pi_{ij}(a, z)}{\partial d_{ij} / d_{ij}}, \\ &= -\frac{\partial \Phi_i(a, z) / \Phi_i(a, z)}{\partial d_{ij} / d_{ij}} - \frac{1}{\sigma_\epsilon} \left[u'(c_{ij}(a, z)) c_{ij}(a, z) \right] + \beta \mathbb{E} \frac{1}{\sigma_\epsilon} \frac{\partial v_i(a', z')}{\partial d_{ij} / d_{ij}}.\end{aligned}$$

To get a sense of things, vary the second term by wealth...

$$\frac{\partial (u'(c_{ij}(a, z)) c_{ij}(a, z))}{\partial a} = u'(c_{ij}(a, z)) \times \text{MPC}_{ij}(a, z) \times \left[-\rho_{ij}(a, z) + 1 \right],$$

where $\rho_{ij}(a, z)$ is the Arrow-Pratt measure of relative risk aversion.

With CRRA, if risk aversion > 1 , then poor, high marginal utility households (who are also high MPC households) are *more elastic relative* to rich households on the extensive margin.

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