Staggered Adjustment and Trade Dynamics

Costas Arkolakis Jonathan Eaton Samuel Kortum

Yale, Penn State, Chicago

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Motivation

- Are new empirical trade models helpful for open economy macro?
- A fundamental incompatibility:
  - *Open economy macro models need*
    a small trade elasticity to explain short-run responses to changes in relative cost
  - *Trade models need*
    a large trade elasticity to explain long-run responses to changes in tariffs
- See the problem in performance of a typical trade model over time

Motivation II

- Bilateral trade share:

$$\pi_{ni}^t \equiv \frac{X_{ni}^t}{X_n^t} = \frac{T_i^t \left(w_i^t d_{ni}^t\right)^{-\theta}}{\sum_k T_k^t \left(w_k^t d_{nk}^t\right)^{-\theta}}$$

- Compare i's and j's shipments to market n:

$$\ln \frac{X_{ni}^t}{X_{nj}^t} = \ln \frac{T_i^t}{T_j^t} - \theta \ln \frac{w_i^t}{w_j^t} - \theta \ln \frac{d_{ni}^t}{d_{nj}^t}$$

- What do changes in relative wages explain?

Motivation II

- Bilateral trade share:

$$\pi_{ni}^{t} \equiv \frac{X_{ni}^{t}}{X_{n}^{t}} = \frac{T_{i}^{t}\left(w_{i}^{t} d_{ni}^{t}\right)^{-\theta}}{\sum_{k} T_{k}^{t}\left(w_{k}^{t} d_{nk}^{t}\right)^{-\theta}}$$

- Compare i's and j's shipments to market n:

$$\ln \frac{X_{ni}^{t}}{X_{nj}^{t}} = \ln \frac{T_{i}^{t}}{T_{j}^{t}} - \theta \ln \frac{w_{i}^{t}}{w_{j}^{t}} - \theta \ln \frac{d_{ni}^{t}}{d_{nj}^{t}}$$

- Specify a regression in changes

$$\ln \frac{\hat{X}_{ni}^{t}}{\hat{X}_{nn}^{t}} = -\theta \ln \frac{\hat{w}_{i}^{t}}{\hat{w}_{n}^{t}} + \varepsilon_{ni}^{t}$$

Motivation III: Pooled Regressions (Annual Differences):

- Explanatory power of the wage changes

$$\ln \frac{\widehat{X}_{ni}^{t}}{\widehat{X}_{nn}^{t}} = -\theta \ln \frac{\widehat{w}_{i}^{t}}{\widehat{w}_{n}^{t}} + \varepsilon_{ni}^{t}$$

$-\widehat{\theta} = 0.4$ (s.e. 0.04) $R^2 = 0.21$

- Explanatory power of encompassing source effect ($S_i^t = T_i^t \left(w_i^t\right)^{-\theta}$)

$$\ln \frac{\widehat{X}_{ni}^{t}}{\widehat{X}_{nn}^{t}} = \ln \frac{\widehat{S}_{i}^{t}}{\widehat{S}_{n}^{t}} + \epsilon_{ni}^{t}$$

$R^2 = 0.47$

Our Goal

- Develop a model that works well at different frequencies
  - Open economy model exploiting information in bilateral trade
- Sacrifice optimizing behavior to make it easier to take to the data

Line of Attack: Staggered Adjustment by Consumers

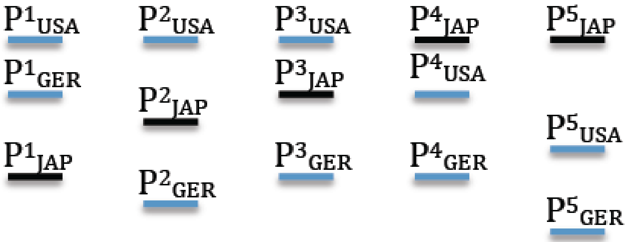
- Basic idea: consumers are slow to switch sources of supply
  - Consistent with evidence on "Customer Loyalty" (Reichheld & Teal '96)
  - Like firms changing prices in Calvo model
- Analysis inspired by Ruhl '05, related to Drozd & Nosal '12
  - Common feature: slow adjustment
  - Ruhl and DN: forward looking decisions by firms (pay sunk cost, build customer base)
  - AEK: passive (staggered) adjustment by consumers

Main Idea in a Nutshell

- A continuum of goods
    - Consumer can search for cheapest supplier only for a fraction of goods each period
        - Sluggish adjustment at the extensive margin (consistent with Baier et al '11)
        - Standard CES Dixit-Stiglitz demand at the intensive margin

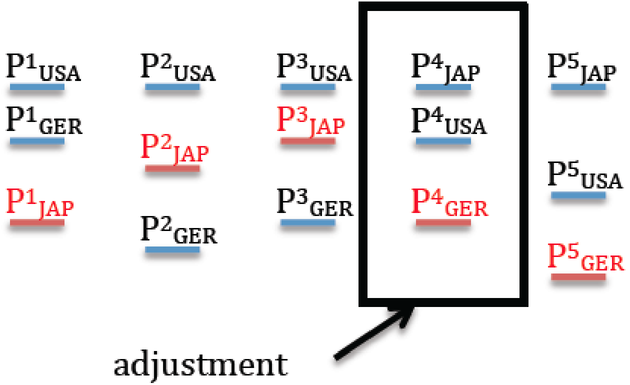
- Firms perfectly competitive
    - Take prices as given

Main Idea: Prices over time



Main Idea: Prices over time & Consumer Choice

Note: Red denotes the chosen supplier.



The Model

Theoretical Framework

- Our model encompasses empirical Ricardian and Armington models
- Adds just one parameter to EK '02, λ : fraction of consumers adjusting
  - $\lambda = 0$ delivers Armington
  - $\lambda = 1$ delivers EK
  - In between is where trade dynamics get interesting

Basics

- Perfect competition, continuum of goods $j \in [0,1]$, integer I countries (denoted n when importing and i when exporting)

- Wage w_i^t, aggregate productivity A_i^t, iceberg trade costs d_{ni}^t
  - Unit cost of i's labor for supplying n:

$$c_{ni}^t \equiv w_i^t d_{ni}^t / A_i^t$$

- A technology for making good j in country i with efficiency z implies price in n of:

$$p_{ni}^t(z) = c_{ni}^t / z$$

Technologies

- New technologies rain down, independently across countries, as in EK'01
- For any good, the number of techniques with efficiency better than z is distributed Poisson $\left(T_i^t z^{-\theta}\right)$
  - Each country more than one available techniques to produce good j

Old EK: Full Adjustment

- Only the best technologies are used in each country, efficiency $z_i^{a,t}(j)$.
- Probability that no technique better than z has arrived (Poisson evaluated at 0) yields Fréchet:

$$\Pr[z_i^{a,t}(j) \leq z] = e^{-T_i^t z^{-\theta}}$$

Old EK: Results

- Price distribution for lowest cost in n:

$$\Pr[p_n^{a,t}(j) \leq p] = G_n^{a,t}(p) = 1 - e^{-\Phi_n^t p^\theta}$$

  - How countries contribute to n: $\Phi_n^t = \sum_k T_k^t \left(c_{nk}^t\right)^{-\theta}$
  - Distribution same for all i conditional on n buying from i

- Share of goods for which i is lowest cost in n:

$$\bar{\pi}_{ni}^{a,t} = \frac{T_i^t \left(c_{ni}^t\right)^{-\theta}}{\Phi_n^t}$$

New AEK: Staggered Adjustment

- Consumer: With probability λ looks everywhere for the lowest-cost supplier, otherwise buys good from same supplier as last year
- Producers: perfectly competitive
  - If $T_i^t = T_i$ (constant technologies) consumer buys country's lowest cost supplier
  - If T_i^t increases consumer may buy from producers with dominated technologies
- We assume that consumers do not observe location of supplier
  - Price by itself does not reveal information for source country (as in EK)
  - Given this environment, optimal to pick cheapest supplier when adjusting

New AEK: Staggered Adjustment

- Fraction of goods n buys from i evolves as:

$$\bar{\pi}_{ni}^{t} = \lambda \bar{\pi}_{ni}^{a,t} + (1-\lambda)\,\bar{\pi}_{ni}^{t-1}$$

- Price distribution for goods purchased from country i evolves as:

$$G_{ni}^{t}(p) = \frac{\lambda \bar{\pi}_{ni}^{a,t}}{\bar{\pi}_{ni}^{t}} G_{n}^{a,t}(p) + \frac{(1-\lambda)\bar{\pi}_{ni}^{t-1}}{\bar{\pi}_{ni}^{t}} G_{ni}^{t-1}\left(\frac{p}{c_{ni}^{t}/c_{ni}^{t-1}}\right)$$

(not the same for all i)

New AEK: Staggered Adjustment

- Fraction of goods n buys from i evolves as:

$$\bar{\pi}_{ni}^{t} = \lambda \bar{\pi}_{ni}^{a,t} + (1-\lambda)\,\bar{\pi}_{ni}^{t-1}$$

- Price distribution for goods purchased from country i evolves as:

$$G_{ni}^{t}(p) = \frac{\lambda \bar{\pi}_{ni}^{a,t}}{\bar{\pi}_{ni}^{t}} G_{n}^{a,t}(p) + \frac{(1-\lambda)\bar{\pi}_{ni}^{t-1}}{\bar{\pi}_{ni}^{t}} G_{ni}^{t-1}\left(\frac{p}{c_{ni}^{t}/c_{ni}^{t-1}}\right)$$

Note: We haven't talked yet about consumer demand.

Consumer Preferences

- Standard Dixit-Stiglitz preferences as in EK

$$x_n^t(p) = \left(\frac{p}{P_n^t}\right)^{-(\sigma-1)} X_n^t \tag{1}$$

with price index

$$\left(P_n^t\right)^{-(\sigma-1)} = \sum_i \bar{\pi}_{ni}^t \left(P_{ni}^t\right)^{-(\sigma-1)}$$

where

$$P_{ni}^t = \left[\int_0^\infty p^{-(\sigma-1)} dG_{ni}^t(p)\right]^{-1/(\sigma-1)}$$

Trade Shares

- Multiplying each side of (1) by $\bar{\pi}^t_{ni}$ then integrating over $G^t_{ni}(p)$ gives the observed trade share:

$$\pi^t_{ni} = \bar{\pi}^t_{ni} \left(\frac{P^t_{ni}}{P^t_n} \right)^{-(\sigma-1)}$$

- For λ low, $\bar{\pi}^t_{ni}$ responds slowly to a change in costs, but its long-run elasticity is always θ
- For λ low, the price index P^t_{ni} moves nearly in proportion to costs, hence affecting the trade share with an elasticity $\sigma - 1$, but in the long run $P^t_{ni} \rightarrow P^t_n$.

Three Key Parameters

- Elasticity of substitution σ
- Elasticity of the extensive margin θ
- Speed of adjustment λ
- Their roles:
  - In Armington $\sigma - 1$ is the trade elasticity
  - In EK θ is the trade elasticity
  - For us, $\sigma - 1$ matters for the short run and θ for the long run, with λ governing the arrival of the long run

Closing the Model

- Static equilibrium allowing for exogenous trade deficits D_n^t
- Labor supply L_i^t is also exogenous
- Labor market equilbrium requires:

$$w_i^t L_i^t = \sum_{n=1}^{I} \pi_{ni}^t \left(w_n^t L_n^t + D_n^t \right)$$

- Want to include a non-traded sector and intermediates, but keep it simple for now.

Model Implications

- Trade elasticity

$$\frac{\partial \pi^t_{ni}}{\partial w_i}\frac{w_i}{\pi^t_{ni}} = -\left[\lambda\theta + (1-\lambda)(\sigma-1)\right](1-\pi^t_{ni}).$$

- Insensitivity of trade shares to wages (if λ and σ are low) makes wages more sensitive to a shock, such as a change in D.
- Real wage (letting $Z^t_n = T^t_n \left(A^t_n\right)^\theta$ combine the two productivity terms):

$$\frac{w^t_n}{P^t_n} = \gamma^{-1}\left(Z^t_n\right)^{1/\theta}\left(\nu^t_n\right)^{1/(\sigma-1)}\left(\bar{\pi}^{a,t}_{nn}\right)^{-1/\theta}$$

Numerical Illustrations

Parameters, Initial Conditions, and Shocks

- Benchmark parameters $\Theta = \{\theta, \sigma, \lambda\}$
  - $\theta = 4$: long-run elasticity estimates (Simonovska Waugh '10, Caliendo Parro '10)
  - $\sigma = 0.5$: short-run elasticity estimates (Reinert '92, Bloningen Wilson '99)
  - $\lambda = 0.05$, $\lambda = 0.20$, or $\lambda = 1$: marketing case studies ($\simeq 0.15$)

- Full-adjustment initial conditions: $\bar{\pi}^{a,0}_{ni} = \pi^0_{ni}$ and $\nu^0_{ni} = \nu^0_n$, $\pi^0_{ni} = \pi^0_{ni}$
- Assume T_i and L_i constant
- Model gives a difference in equation on past trade shares (&changes in technology etc)
  - Use it to solve for equilibrium recursively

Data

- Bilateral trade in manufactures among G6 countries and ROW
- Annual 1991-2006
- Manufacturing gross production for Y_i

Experiment I: Balancing Trade

- Start from initial condition in 2006, then permanently adjust to balanced trade
- Japan starts in surplus; United Kingdom and the United States in deficit
- Show outcomes for $i = J, UK\ , USA$:
  1. Wage w_i^t (relative to world manufacturing production)
  2. Real wage w_i^t / P_i^t
  3. Terms of trade (export price over import price)
  4. Domestic share, π_{ii}^t

Experiment I: Trade Balance after 2006

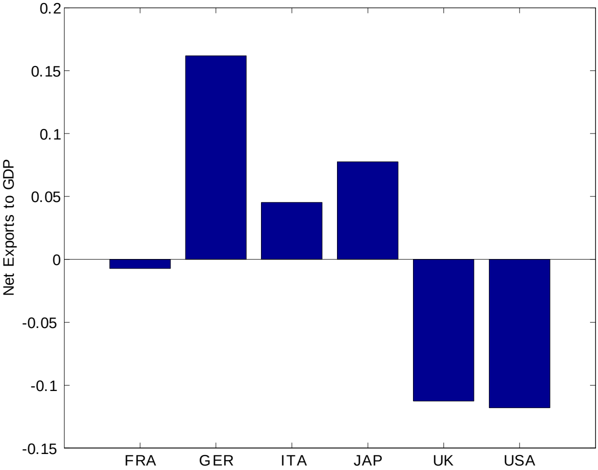


Figure 2: Balanced Trade with High Lambda (DEK)

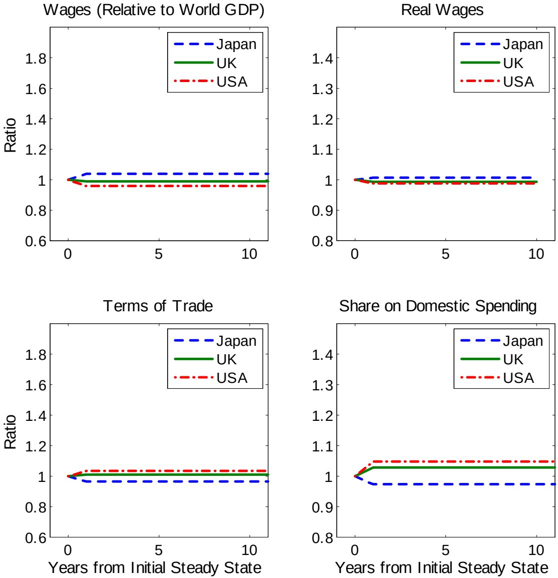


Figure 3: Balanced Trade with Medium Lambda

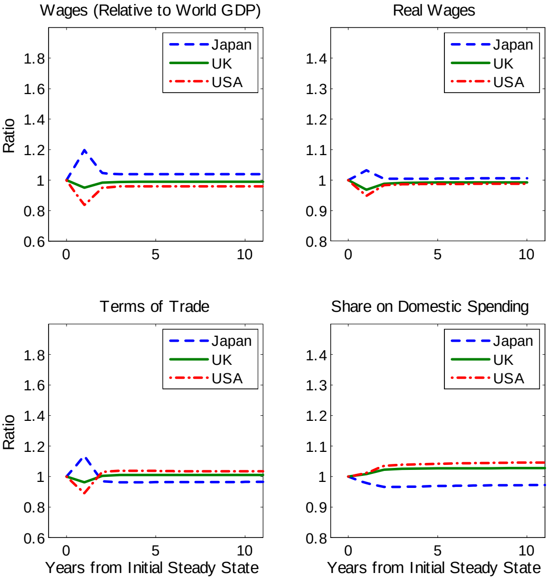
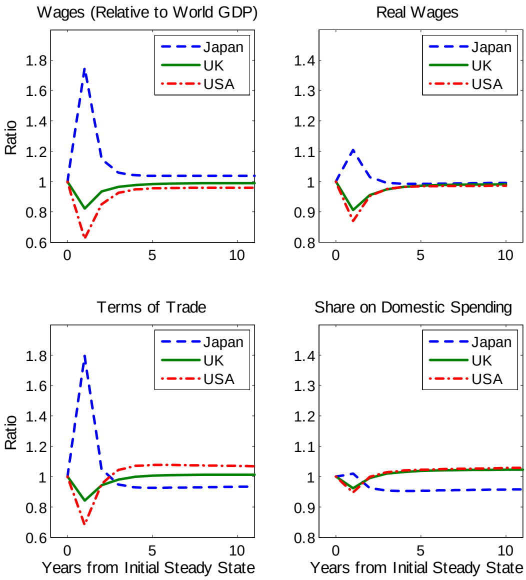


Figure 4: Balanced Trade with Low Lambda

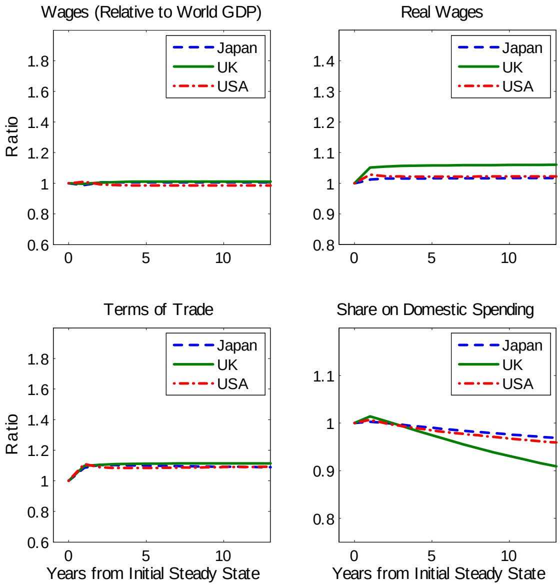


Experiment II: Trade Liberalization

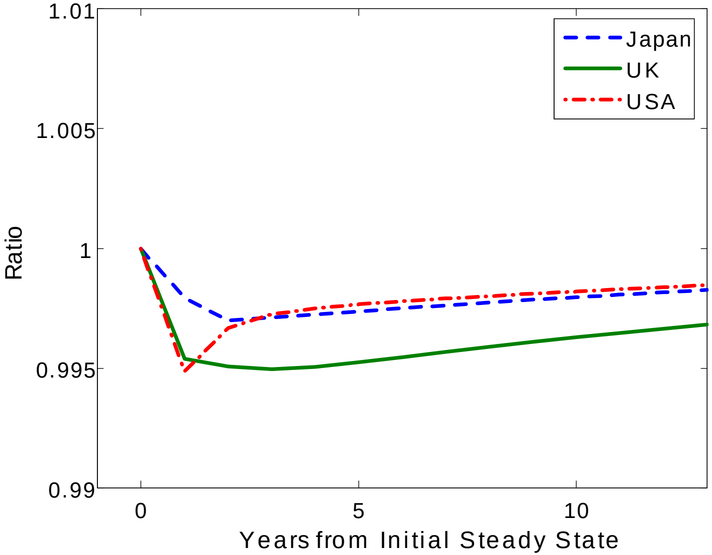
- Start from initial condition in 2006, then $\hat{d}_{ni}^{2007} = 1/(1.1)$ for all $n \neq i$
- Set $\lambda = 0.05$
- Outcomes for $i = J,\ UK\ ,\ USA$:

  1. Wage w_i^t (r-elative to world manufacturing production)
  2. Real wage w_i^t / P_i^t
  3. Terms of trade (export price over import price)
  4. Domestic share, π_{ii}^t

Figure 5: Trade Liberalization Outcomes



Trade Liberalization: Welfare Loss due to Slow Adjustment



Experiment III: Estimate Trade Elasticities

- Simulate using actual deficits 1992-2006
- Productivity shocks log normal: mean and std. deviation of growth 0.01
- Generate 100 separate data sets by repeatedly simulating the model
- Run the following short-run regression on both the simulated and the actual data:

$$\ln \frac{\widehat{\pi}_{ni}^{t}}{\widehat{\pi}_{nn}^{t}} = \varepsilon_S \ln \frac{\widehat{w}_i^t}{\widehat{w}_n^t} + u_{ni}^t \text{ for all } t, n, i \neq n$$

Short-Run Regression Results

	$\lambda = 0.05$	$\lambda = 0.2$	$\lambda = 1$	Data
mean	0.384	-0.017	-1.17	0.41
std. deviation	0.003	0.017	0.239	0.04
model elasticity	0.275	-0.400	-4.00	

Long-Run Regression

- Simulate permanent removal of a 10% tariff on ROW imports, in 1992
- Captured by $\hat{d}_{ni}^{1992} = 1/(1.1)$ when $n = ROW$
- We also include the same shocks to deficits and productivity as in the previous exercise
- Construct the Head and Ries '01 index

$$H_{ni}^{t} = \frac{\pi_{ni}^{t}}{\pi_{nn}^{t}} \frac{\pi_{in}^{t}}{\pi_{ii}^{t}}$$

- Run the long-run regression:

$$\ln\left(\frac{H_{ni}^{2006}}{H_{ni}^{1991}}\right) = \varepsilon_L \ln\left(\hat{d}_{ni}^{1992} \hat{d}_{in}^{1992}\right) + u_{ni} \text{ for all } n, i \leq n$$

- Mean OLS estimate is -3.62 when $\lambda = 0.05$ (long-run elasticity would have been $\theta = 4$)

Towards Estimation

Equations for Estimation

- Let $\tau_i^t = \ln \hat{Z}_i^t$ and $\varepsilon_{ni}^t = -\theta \ln \hat{d}_{ni}^t$ be random shocks:

$$\widehat{\bar{\pi}}_{ni}^{a,t} = \frac{\exp\left(\tau_i^t + \varepsilon_{ni}^t\right)\left(\hat{w}_i^t\right)^{-\theta}}{\sum_k \bar{\pi}_{ni}^{a,t-1} \exp\left(\tau_k^t + \varepsilon_{nk}^t\right)\left(\hat{w}_k^t\right)^{-\theta}}$$

- Let $g_T = \hat{T}_i^t$:

$$\nu_{ni}^t = \lambda \bar{\pi}_{ni}^{a,t} + (1-\lambda)\left(\frac{\widehat{\bar{\pi}}_{ni}^{a,t}}{g_T}\right)^{\frac{\sigma-1}{\theta}} \nu_{ni}^{t-1}$$

- Given full-adjustment initial conditions at $t = 0$ and observed wage changes $\hat{w}_i^t$, want to perfectly fit data on bilateral trade shares over time:

$$\pi_{ni}^t = \frac{\nu_{ni}^t}{\sum \nu_{nk}^t}$$

Moment Conditions

- To identify the parameters $\Theta = \{\theta, \sigma, \lambda, g_T\}$ impose orthogonality conditions between the shocks and observed deficits D_n^t
- Gives a vector of moments $f(\tau, \varepsilon)$ that should be close to zero
- The identification power of deficits comes from the labor market equilibrium conditions, which imply that running a larger deficit raises a country's wage

A Procedure

- Want to exploit recent work on structural estimation using Mathematical Programming with Equilibrium Constraints (MPEC): Su Judd '10
- Our model fits nicely into the setting explored by Dube Fox Su '09:

$$\begin{array}{rc} & \min_{\Theta,\tau,\varepsilon} f(\tau,\varepsilon)'\Omega f(\tau,\varepsilon) \\ \text{subject to} & \pi(\tau,\varepsilon;\Theta) = \Pi \end{array}$$

  - Note I: since π is a constraint, we also fit wages by labor market clearing Note II: trade shares are like market shares in BLP
- Its just a big constrained minimization problem

Appendix

Motivation II

- Bilateral trade share:

$$\frac{X_{ni}^t}{X_n^t} = \pi_{ni}^t = \frac{T_i^t \left(w_i^t d_{ni}^t\right)^{-\theta}}{\sum_k T_k^t \left(w_k^t d_{nk}^t\right)^{-\theta}}$$

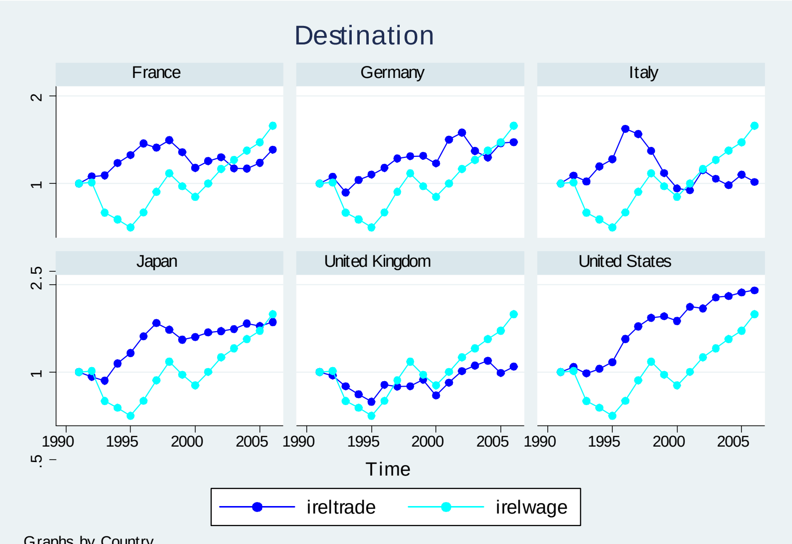
- Compare i's and j's shipments to market n:

$$\ln \frac{X_{ni}^t}{X_{nj}^t} = \ln \frac{T_i^t}{T_j^t} - \theta \ln \frac{w_i^t}{w_j^t} - \theta \ln \frac{d_{ni}^t}{d_{nj}^t}$$

- What do changes in relative wages explain?
- Set: United Kingdom (i), Japan (j), each G6 country (n's)

Motivation III

- UK/Japan wage (falls then rises). Manufacturing shipments (UK vs. Japan) to G6 destinations:



Three Key Equations for Simulation

- Letting $\hat{Z}_i^t = \hat{T}_i^t \left(\hat{A}_i^t\right)^\theta$ capture productivity change (where $\hat{x}^t = x^t / x^{t-1}$):

$$\widehat{\bar{\pi}}_{ni}^{a,t} = \frac{\hat{Z}_i^t \left(\hat{w}_i^t \hat{d}_{ni}^t\right)^{-\theta}}{\sum_k \bar{\pi}_{ni}^{a,t-1} \hat{Z}_k^t \left(\hat{w}_k^t \hat{d}_{nk}^t\right)^{-\theta}}$$

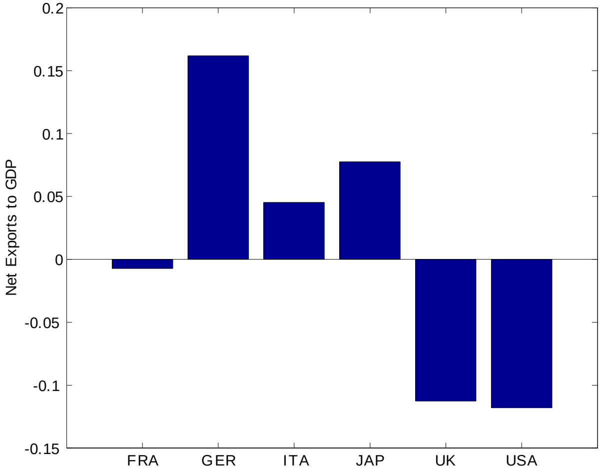
- Letting $\nu_{ni}^t = \pi_{ni}^t \left(\frac{P_n^t}{P_n^{a,t}}\right)^{-(\sigma-1)}$ so that trade shares are $\pi_{ni}^t = \nu_{ni}^t / \sum \nu_{nk}^t$:

$$\hat{\nu}_{ni}^t = \lambda \widehat{\bar{\pi}}_{ni}^{a,t} \frac{\bar{\pi}_{ni}^{a,t-1}}{\nu_{ni}^{t-1}} + (1-\lambda) \left(\frac{\widehat{\bar{\pi}}_{ni}^{a,t}}{\hat{T}_i^t}\right)^{\frac{\sigma-1}{\theta}}$$

- Letting $Y_i^t = w_i^t L_i^t$ we have:

$$\hat{w}_i^t \hat{L}_i^t Y_i^{t-1} = \sum_{n=1}^{I} \pi_{ni}^t \left(\hat{w}_n^t \hat{L}_n^t Y_n^{t-1} + D_n^t\right)$$

Experiment I: Trade Balance after 2006



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