GT CREST-LMA: Pricing-to-Market, Trade Costs, and International Relative Prices

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Empirical motivation

- US PPI-based RER is highly volatile
- Under PPP, this should induce a high volatility in the US ToT (M prices should move with the US' main trading partners' PPI and X prices with the US PPI)

$$\left(\frac{\hat{PPI}}{PPI^*}\right) = \left(\frac{\hat{EPI}}{IPI}\right) + \left(\frac{\hat{PPI}}{EPI}\right) + \left(\frac{\hat{IPI}}{PPI^*}\right) = \left(\frac{\hat{EPI}}{IPI}\right)$$

- Under PPP, the CPI-based RER should be smoother than the PPI-based RER as CPIs are a weighted average of changes in domestic producer prices and import prices and international trade mitigates the impact of fluctuations in relative PPIs

$$\hat{CPI} = \hat{PPI} + s_M(\hat{IPI} - \hat{EPI})$$

$$\Rightarrow \quad \frac{\hat{CPI} - \hat{CPI}^*}{\hat{PPI} - \hat{PPI}^*} \simeq 1 - 2s_M \frac{\hat{EPI} - \hat{IPI}}{\hat{PPI} - \hat{PPI}^*} = 1 - 2s_M$$

Empirical motivation (2)

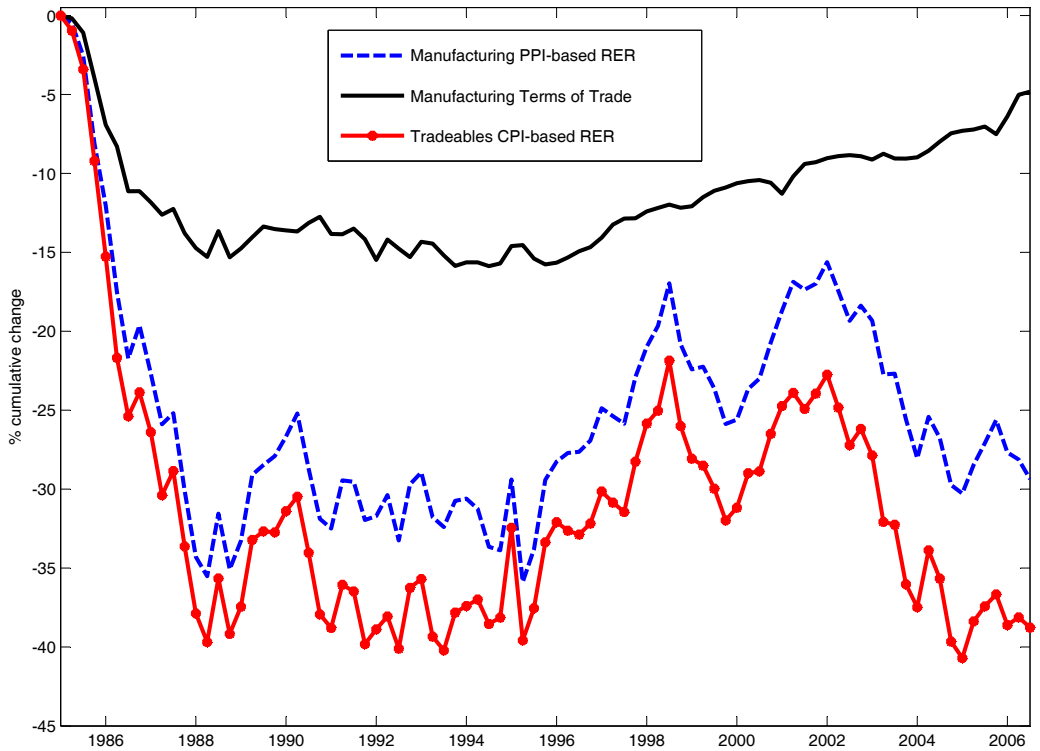
- In the data, ToTs are less volatile than PPI-based RERs for manufactured goods and CPI-based RERs are as volatile as PPI-based RERs.
- Explanation: Aggregate export and import prices show systematic deviations from relative PPP $\longrightarrow$ Pricing-to-Market

$$\left(\frac{\hat{PPI}}{EPI}\right) + \left(\frac{\hat{IPI}}{PPI^*}\right) \neq 0$$

$$\frac{\hat{EPI} - \hat{IPI}}{\hat{PPI} - \hat{PPI}^*} < 1$$

Empirical motivation (3)

Figure 1: U.S., Terms of Trade and Trade-Weighted Real Exchange Rates



Sources: Manufactured X and M price indices from the BLS. RERs defined as US price over a trade-weighted average of the US trading partners' prices. PPIs cover manufactured goods and CPIs exclude services

- ToTs are less volatile than PPI-RERs ($\sigma_{ToT}/\sigma_{PPI} = 1/3 - 2/3$)
- Fluctuations in CPI-based RERs are roughly as large as for PPI-RERs

Empirical motivation (3)

	StDev relative to PPI/PPI^*		Correlation with PPI/PPI^*	
	PPI/EPI	IPI/PPI^*	PPI/EPI	IPI/PPI^*
USA	.32	.67	.45	.82
Japan	.53	.42	.87	.72
Germany	.38	.69	.24	.70
France	.64	.66	.70	.70
Italy	.69	.72	.59	.54
UK	.44	.63	.62	.86
Canada	.50	.57	.63	.53

- Deviations from relative PPP are 1/3 to 2/3 as large as fluctuations in PPI-RERs and positively correlated with movements in the PPI-RER
- Deviations from relative PPP also observed in disaggregated data (but heterogeneity across sectors)

Objective

- Build a model of international trade and international relative prices to account for these aggregate price observations
- Deviations from aggregate relative PPP as a result of the decisions of individual firms to PTM
- Key ingredients:
  - Imperfect competition with variable markups (Quantity competition à la Cournot $\longrightarrow$ Markups depend on market shares) $\longrightarrow$ Incentive to price-to-market
  - International trade costs $\longrightarrow$ Ability to price-to-market and impact on optimal markups
- Calibrate the model using data on trade volumes and market structures

Main results

- Firms price-to-market in response to aggregate shocks
- Large firms are more prone to PTM $\longrightarrow$ At the aggregate level, pass-through is lower in sectors with a high dispersion of costs.
- Calibration results show that the model is able to reproduce
  - i) movements in the ToTs that are smaller than corresponding movements in the PPI-based RER for manufactures, and
  - ii) movements in the CPI-based RER that are similar to corresponding movements in the PPI-based RER.
- Both variable markups and international trade costs are crucial in generating these results:
  - Without variable markups, shocks to the marginal cost of production leave the ratio of export to producer prices unchanged
  - Without international trade costs, the extent of competition is identical in both markets and markups move identically following a cost shock
  - International trade costs also justify imports form a small share of the CPI, which is at the root of the good match of CPI and PPI volatilities.

Hypotheses of the model: Households

- Two symmetric countries (indexed by $i = 1, 2$) produce and trade a continuum of goods subject to frictions in international goods markets.
- Aggregate shocks to productivity as the driving force behind fluctuations in international relative prices.
- Preferences in country i:

$$E_0 \sum_{t=0}^{\infty} \beta^t u(c_{it}, 1 - l_{it})$$

where β is the discount factor, and $u(c, 1-l) = log[c^{\mu}(1-l)^{1-\mu}]$ with c_{it} final consumption and l_{it} working hours of the representative household.

- Households in each country trade a complete set of international assets $\Rightarrow$ Nominal consumptions are always equalized across countries.

Hypotheses of the model: Firms

- In each country i and sector j, there are K domestic firms and an additional K foreign firms that may, in equilibrium, sell goods in that sector. Firms $k \in [1, K]$ are domestic and $k \in [K+1, 2K]$ are foreign. K taken as exogenous (no decision to enter the market) and assumed small (oligopolistic competition).
- Output in each sector is given by:

$$y_{ijt} = \left[\sum_{k=1}^{2K} q_{ijkt}^{\frac{\rho-1}{\rho}} \right]^{\frac{\rho}{\rho-1}}, \quad \rho < \infty$$

where q_{ijkt} denotes sales in country i of firm k in sector j.

- Sectors are then further aggregated into a consumption composite, produced by a competitive firm using the output of sectors as input:

$$c_{it} = \left[\int_0^1 y_{ijt}^{\frac{\eta-1}{\eta}} dj \right]^{\frac{\eta}{\eta-1}}, \quad 1 < \eta < \rho$$

Hypotheses of the model: Firms (2)

- Each firm has a constant returns to scale production function that has labor as the only input:

$$y_{ikt} = A_{it} z_k l_{ikt}$$

  where z_k differs across firms but is fixed over time and A_{it} denotes aggregate productivity that affects all firms based in country i. z is drawn from a log-normal distribution, $N(0, \theta)$ (sector-specific).
- In addition to the production costs, there are costs of international trade:
  - International trade is prohibitively costly for final consumption.
  - The output of firms can be traded, under two type of costs: a fixed labor cost F to export and an iceberg type marginal cost of exporting τ.
- Firms play a static game of quantity competition: choose quantities q_{ijkt} taking as given the quantities chosen by other firms, the domestic wage W_i, the final consumption price P_i and the aggregate quantity c_i but recognizing that sectoral prices P_{ij} and quantities y_{ij} are endogenous to their choice.

Household's program

$$\begin{cases} \max_{c_{is}, l_{is}, b_{is+1}} E_0 \sum_{t=0}^{\infty} \beta^t u(c_{it}, 1 - l_{it}) \\ u.c. \quad P_{it} c_{it} + b_{it+1} = W_{it} l_{it} + (1 + r) b_{it} \end{cases}$$

$\Rightarrow$ Intratemporal arbitrage condition between consumption and leisure:

$$\frac{1 - \mu}{\mu} \frac{c_{it}}{1 - l_{it}} = \frac{W_{it}}{P_{it}}$$

$\Rightarrow$ Euler equation:

$$\beta \frac{P_{it}}{P_{it+1}} (1 + r) u'_c(c_{it+1}, 1 - l_{it+1}) = u'_c(c_{it}, 1 - l_{it})$$

$\Rightarrow$ Under complete markets:

$$P_{1t} c_{1t} = P_{2t} c_{2t}$$

Optimal demands

- At the sectoral level:
  Max c_{it} s.t. budget constraint

$$\Rightarrow \quad y_{ijt} = \left(\frac{P_{ijt}}{P_{it}}\right)^{-\eta} c_{it}$$

$$P_{it} = \left[\int_0^1 P_{ijt}^{1-\eta} dj\right]^{\frac{1}{1-\eta}}$$

- At the firm level:
  Max y_{ijt} s.t. budget constraint

$$\Rightarrow \quad q_{ijkt} = \left(\frac{P_{ijkt}}{P_{ijt}}\right)^{-\rho} y_{ijt}$$

$$P_{ijt} = \left[\sum_{k=1}^{2K} P_{ijkt}^{1-\rho}\right]^{\frac{1}{1-\rho}}$$

Firms' behaviour without trade

- Suppose for now that only the K domestic firms in each country/sector sell goods
- Equilibrium prices and quantities obtained from:

$$\begin{cases} \max_{P_{ijkt}, q_{ijkt}} \left[P_{ijkt} q_{ijkt} - \frac{W_{it}}{z_k A_{it}} q_{ijkt} \right] \\ s.t. \quad \frac{P_{ijkt}}{P_{it}} = \left(\frac{q_{ijkt}}{y_{ijt}} \right)^{-1/\rho} \left(\frac{y_{ijt}}{c_{it}} \right)^{-1/\eta} \\ y_{ijt} = \left[\sum_k q_{ijkt}^{\frac{\rho-1}{\rho}} \right]^{\frac{\rho}{\rho-1}} \end{cases}$$

- Optimal prices:

$$P_{ijkt} = \frac{\varepsilon(s_{ijkt})}{\varepsilon(s_{ijkt}) - 1} \frac{W_{it}}{z_k A_{it}}$$

where $s_{ijkt} \equiv \frac{P_{ijkt} q_{ijkt}}{\sum_k P_{ijkt} q_{ijkt}} = \frac{dy_{ijt}/y_{ijt}}{dq_{ijkt}/q_{ijkt}}$ is the firm's market share in country i and $\varepsilon(s_{ijkt}) \equiv \left[\frac{1}{\rho}(1 - s_{ijkt}) + \frac{1}{\eta} s_{ijkt} \right]^{-1}$ is the perceived elasticity of demand.

- Optimal quantities come immediately

Firms' behaviour without trade (2)

- Limit cases:
  - $K \to \infty \Rightarrow s \to 0 \Rightarrow \varepsilon(s) = \rho$: the firm only perceives the sectoral elasticity of demand ρ and chooses a markup equal to $\rho/(\rho - 1)$.
  - $s \to 1 \Rightarrow \varepsilon(s) = \eta$: the firm only perceives the (lower) elasticity of demand across sectors and sets a higher markup equal to $\eta/(\eta - 1)$
  - $\eta = \rho$: the model reduces to the standard model of monopolistic competition with a constant markup of price over marginal cost given by $\rho/(\rho - 1)$ (Ghironi & Mélitz, 2005).
- When $\rho > \eta$, firms with a sectoral market share between zero and one choose a markup that increases smoothly with that market share (rq: idem under Bertrand competition).

$\Rightarrow$ Prices and costs are not linearly related in the model $\to$ incomplete pass-through of changes in cost: an increase in a firm's relative marginal cost induces a market share loss and a markup reduction.

$\Rightarrow$ PTM will naturally arise if a change in costs for one firm leads to a change in markups that is different in each market in which this firm competes $\to$ Requires international trade costs (lower market share in the export market)

Export decisions

- To determine how many foreign firms pay the fixed trade cost to supply the domestic market, an iterative procedure is used: foreign firms consider entry sequentially in reverse order of unit costs (the lowest cost producer $k+1$ enters, if it still makes profits, the second lowest cost producer $k+2$ enters, etc.)
- Optimal price of the lowest cost foreign firm:

$$P_{ijK+1t} = \frac{\varepsilon(s_{ijK+1t})}{\varepsilon(s_{ijK+1t}) - 1} \frac{\tau W_{i't}}{z_{K+1} A_{i't}}$$

$\Rightarrow$ Used to compute the sectoral quantity and price and the demand addressed to the firm $\rightarrow$ Expected profits from foreign sales $\rightarrow$ Entry if profits are higher than the fixed cost $W_{i't}F$

- if her aggregate profit is strictly positive, the second lowest cost producer is likely to enter market i as well.

$\Rightarrow$ Iterating over firms gives a set of equilibrium prices P_{ijkt} and a number of foreign firms supplying the domestic market in sector j, given fixed aggregate prices, wages, and quantities.

General equilibrium

- W_2 chosen as numéraire

1. Solve for the number of firms and prices in every sector in both countries for given P_1, P_2, c_1, c_2 and W_1
2. Use individual prices to get aggregate and sectoral prices
3. Use quantities produced by each firm and the amount of fixed costs to get aggregate labor demand
4. Combine the labor-market equilibrium together with the household's first order conditions to get a fixed point in the aggregate variables $\{P_i, W_i, c_i, l_i\}_{i=1}^{2}$

Calibration

- Objective: Study the response of international relative prices to an exogenous shock to aggregate productivity in a calibrated version of the model
- Parameters of the utility function set at standard values: $\beta = .96$, $\mu = 2/3$
- 20,000 sectors (more disaggregated than the 10-digit level of the NAICS nomenclature) and 20 firms per sector
- $\eta \simeq 1$ (Cobb-Douglas), $\rho = 10$
- θ, τ and F matching observations in the US economy on the overall volume of trade, the fraction of firms that export and a measure of industry concentration at the sectoral level (symmetric equilibrium $A_1 = A_2$): $\theta = .385$, $\tau = 1.45$, share of labor force in export fixed effects=.08%

Calibration (2)

- Alternative parameter settings: i) $\rho = \eta = 3$ (constant markups), ii) $\tau = 1$ and $F = 0$ (frictionless trade)
- Shock: one percent increase in relative aggregate costs $(W_1/A_1)/(W_2/A_2)$
- Construct sectoral and aggregate PPI, IPI, EPI, CPI: price indices using the predicted sales (or expenditures) as weights
- Remark: Treat the problem of extensive effects by attributing a price change equal to the overall change in the index for goods that switch export or import status as a result of the shock

Calibration results

Table: Impact of a 1% shock on relative production costs

	Complete Model	Constant Markups	Frictionless Trade
PPI-based RER (decomposition %)			
Terms-of-trade, country 1	53.4%	100%	100%
PPI/Export price, country 1	23.1%	0%	0%
Export price/PPI, country 2	23.6%	0%	0%
PPI, country 1	0.86%	1%	0.76%
Export price, country 1	0.69%	1%	0.76%
Import price, country 1	0.31%	0%	0.23%
PPI, country 2	0.14%	0%	0.23%
CPI-RER/PPI-RER	82.3%	66.9%	0%

Source: Atkeson & Burstein (2008). Benchmark calibration.

Calibration results (2): Terms-of-Trade

- Movements in the ToT are 53% as large as movements in the PPI-RER $\Rightarrow$ Reproduces the first fact
- Explanation: Large deviations from relative PPP due to individual decisions to PTM: $g_{PPI} > g_{EPI}$ and $g_{IPI} > g_{PPI^*} \Rightarrow$ Positive correlation in the movements of PPI/EPI and IPI/PPI^* with PPI/PPI^*
- Both variable markups and trade costs are necessary to get this result:
  - Constant markups $\longrightarrow$ Complete pass-through $\longrightarrow$ Relative PPP at the good level and no impact at the extensive margin
  - Frictionless trade $\longrightarrow$ market shares are identical in the domestic and foreign markets and all firms serve both markets $\longrightarrow$ Incomplete pass-through but equal in both countries $\longrightarrow$ No PTM

Calibration results (3): CPI-based RER

- Movements in the CPI-based RER are 83% as large as movements in the PPI-based RER
- Explanation: Low (calibrated) share of imports + deviations from relative PPP
- Relative volatility of CPI-RERs much lower in the constant markups and the frictionless trade models:
  - Frictionless trade: relative PPP + identical consumption baskets ($s_M = .5$) $\rightarrow$ CPI-based RER does not move at all
  - Constant markups: relative PPP but different consumption baskets ($s_M = .165$) $\rightarrow$ Movements in the CPI-based RER are 67% as large as movements in the PPI-based RER

Adding non-traded distribution costs

- In the simulation, the relative volatility of the CPI-based RER w.r.t. the PPI-based RER is still too low

$\Rightarrow$ Solution: Add non-tradeable distribution costs to reduce the share of traded goods in the CPI

- Final consumption requires adding distribution services in the form of non-tradeable goods (labor inputs in the model):

$$c_{it} = \left[\int_0^1 \left(y_{ijt}^{1-\phi} d_{ijt}^{\phi} \right)^{\frac{\eta-1}{\eta}} dj \right]^{\frac{\eta}{\eta-1}}, \quad 1 < \eta < \rho$$

$\Rightarrow$ Distribution costs account for a constant share of retail prices for each individual good $\rightarrow$ Do not change PTM behaviors

- When ϕ is calibrated to 0.5, changes in the CPI-based RER are 111% as large as changes in the PPI-based RER
- Role of distribution costs: Reduce s_M + Amplify fluctuations in CPIs as fluctuations in the relative price of distribution are larger than fluctuations in the PPI-based RER (no incomplete pass-through)

Individual PTM behaviors

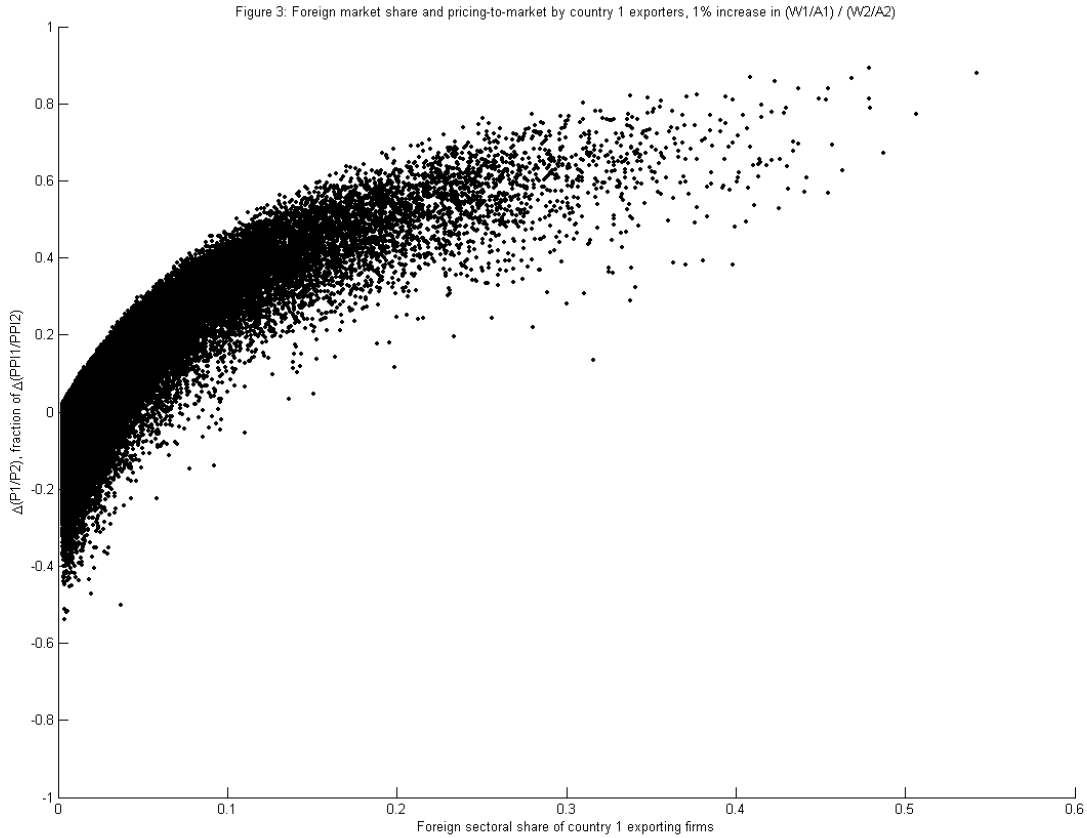
- Firms PTM by adjusting their markup to changes in their market share

$\Rightarrow$ Extent of PTM depends on the exact configuration of costs across firms in the sector

$\Rightarrow$ Productivity heterogeneity generates price heterogeneity

- In the simulations, *PPI* raises in comparison to *EPI* because large firms PTM and dominate the index

Individual PTM behaviors (2)



Sources: Atkeson & Burstein (2008). Simulation of a 1% increase in country 1's productivity

Individual PTM behaviors (3)

- More productive firms are more prone to PTM:

$$\hat{P}_{1k} - \hat{P}_{2k} = \Gamma(s_{1k})\hat{s}_{1k} - \Gamma(s_{2k})\hat{s}_{2k}$$
$$= \left[\frac{1}{1+\Gamma(s_{1k})(\rho-1)} - \frac{1}{1+\Gamma(s_{2k})(\rho-1)}\right](\hat{w}_{1k} - \hat{P}_1) + \frac{\Gamma(s_{2k}(\rho-1)}{1+\Gamma(s_{2k})(\rho-1)}(\hat{P}_1 - \hat{P}_2)$$

  where $\Gamma(s_{1k})$ is the elasticity of the markup w.r.t. market share, which is increasing and convex on s

- The first term captures the direct effect of a change in the firm's costs and induces a relative raise in the firm's export (as $s_{1k} > s_{2k} \Rightarrow \Gamma(s_{1k}) > \Gamma(s_{2k})$)
- The second term captures the indirect effect coming from strategic interactions between firms which induces a relative drop in the firm's export: As the foreign sectoral price decreases w.r.t. the domestic price, the firm reduces its foreign markup
- The second effect dominates for more productive firms

Individual PTM behaviors (4)

- Heterogeneity in PTM behaviors across firms may explain heterogeneity in the magnitude of PT across countries and sectors
- In the simulations, sectors are homogeneous except for the configuration of cost realizations $\rightarrow$ Heterogeneity in the deviations from relative PPP as measured by $\frac{\hat{PPI}_j - \hat{EPI}_j}{PPI - PPI^*}$: mean=14%, StDev=16%
- Remark: Without heterogeneity in productivity or export participation, PTM goes in the wrong direction: Following a relative cost shock, firms raise export prices w.r.t. domestic prices $\rightarrow$ negative comovement of PPI/EPI and the PPI-based RER

Sensitivity analysis

- Increasing the number of firms per sector:
  Does not necessarily reduce PPP deviations as the productivities of the few more productive must grow to match evidence on the Herfindahl index
- Reducing the gap between ρ and η:
  Reduces aggregate deviations from relative PPP but international price moveme,ts are still substantial
- Using an exponential distribution of productivities (Eaton & Kortum, 2002):
  Movements in the ToT are smoother
- Variant with no variable trade cost but home bias in consumption:
  Similar implications

Conclusion

- Model that helps reproducing empirical evidence on international relative prices
- Explanation based on real factors: Firms have an *incentive* to PTM under imperfect competition and costly trade $\Rightarrow$ Allows reproducing persistent deviations from PPP ($\neq$ PTM models based on price stickiness)
- Structure of the model may be used to analyze other sources of international relative cost shocks (monetary shocks with nominal rigidities, limited participation, etc.)
- In the model, optimal PTM is obtained thanks to oligopolistic competition between heterogeneous firms $\rightarrow$ Possible testable predictions using firm-level data