# Pricing to Market in Business Cycle Models

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# Goal: Evaluation of PTM Macro Theory

- Aimed at explaining ubiquitous PTM pattern in data:

$$PT \equiv \frac{\partial p_x}{\partial x} > 0$$

  - driven by

$$\frac{\partial (p_x / p_d)}{\partial x} > 0$$

- Structure of PTM theories:
  - Micro-founded story for: segmentation + imperfect competition
  - Applicable to large scale macro models (DSGE)

# Example: Aggregate PTM in the US

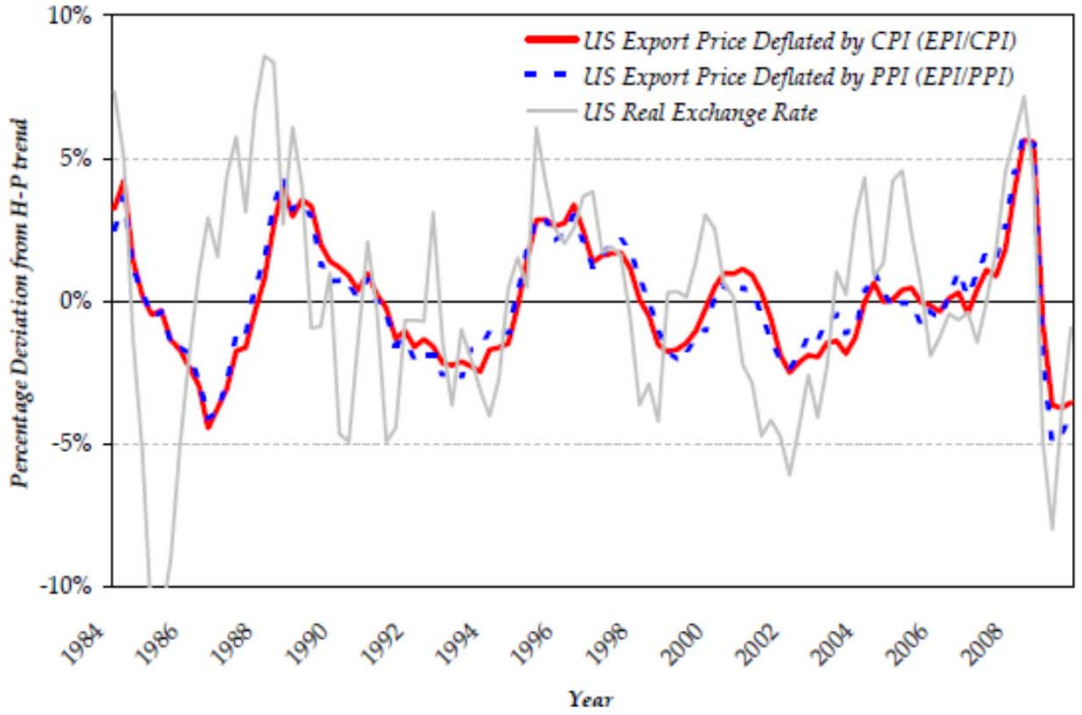


Figure 1: Dynamics of Aggregate Export Price in the US.

# Specific Question

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- Are PTM mechanisms useful for policy/DSGE modeling?
  - Motivated by the very reasons why we need PTM theory:

    1 .Understand sources of segmentation and frictions in commodity markets on the macro level

    2. Get GE right to model related questions (e.g. policy)

# Specific Question

- Are PTM mechanisms useful for policy/DSGE modeling?
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    2. Get GE right to model related questions (e.g. policy)

# Details

- Look at 4 x leading theories from the literature:
  - *Costly distribution* – based on Corsetti and Dedola (2002), also related to Kimball (1995)
  - *Consumer/retail search* – based on Alessandria (2009)
  - *Industry aggregation* – based on Atkeson and Burstein (2009)
  - *Habit formation* – based on Ravn et al. (2010)
  - Possible to incorporate other work (e.g. our own)
- Propose unified framework to perform meaningful comparison
  - Do PTM frictions affect model performance in other dimensions
  - Do they work universally or only under certain (specific) conditions

# Example of Policy Relevance

- PTM useful for DSGE modeling under *fully* endogenous price stickiness (e.g. menu cost model)
  - *Endogeneity* creates an immediate issue in open economy context:
    - Volatile marginal costs across countries due to volatile exchange rates → consistent with high cost of adjustment of prices to deliver quantitatively meaningful deviations from the law of one price (LOP)
    - Not so volatile within country marginal costs → consistent with moderate or low cost of adjustment of prices
- PTM resolves this issue by bringing relative international prices closer to data, enhancing the power of sticky price models to match both cross-country pricing and within country pricing

# Findings

- Most frictions require special setting of model parameters, implying restriction on calibration
- Some affect model performance in other respects (quantities)
- Not all work with any types of driving shocks

# Specific Findings

- Consumer search and cost of distribution models
  - Require aggregate/industry markups above 50%
- Industry aggregation model
  - Requires special setting of international elasticity
  - Adversely affects dynamics of quantities over the business cycle
- Habit model
  - Work only with special kind of shocks
  - Implies counterfactual PTM pattern for usual types of shocks

# Disclaimer: What We Do Not Say!

- We do not overturn any of the findings in the original papers!

# Models

# Common Features (Same GE Framework)

- Basic open macro GE
  - Two symmetric countries
  - Country specific goods with CES aggregators (everywhere)
  - Home-bias
  - Productivity shocks

- On the side:
  - Other shocks, different trade costs, non-tradable goods.

Country 1

Country 2

$u(c)$

Final / consumer level

$c + i = G(\text{“}D\text{”}, \text{“}F\text{”})$

Sectoral level

$D \leftarrow \text{“}d\text{”} \quad F \leftarrow \text{“}f\text{”}$

Industry level

$\text{“}d\text{”} \leftarrow zF(k, l)$

Asset trade

$x = \frac{u_c^*}{u_c}$

**No trade in goods on the upper levels of aggregation**

Trade in intermediate goods

$u(c^*)$

$c^* + i^* = G(\text{“}F^*\text{”}, \text{“}D^*\text{”})$

$D^* \leftarrow \text{“}d\text{”} \quad F^* \leftarrow \text{“}f\text{”}$

$\text{“}f\text{”} \leftarrow z^* F(k^*, l^*)$

# Prices (some notation for later)

- Price of consumption in each country = 1 (at all times)
- Price of composite goods $P_D, P_F, P_D^*, P_F^*$
- Price of intermediate goods/ varieties $p_d, p_f, p_d^*, p_f^*$
- Focus on export price in domestic unit $p_x = x p_d^*$
- Marginal cost and x-rate key source of fluctuations in prices

$$v, v^*$$

# Specific Features

# Frictionless Benchmark (BKK)

- Trivial sectoral aggregation (same variety within country)

$$P_d = p_d$$

- Perfect competition in intermediate sector (MC pricing)

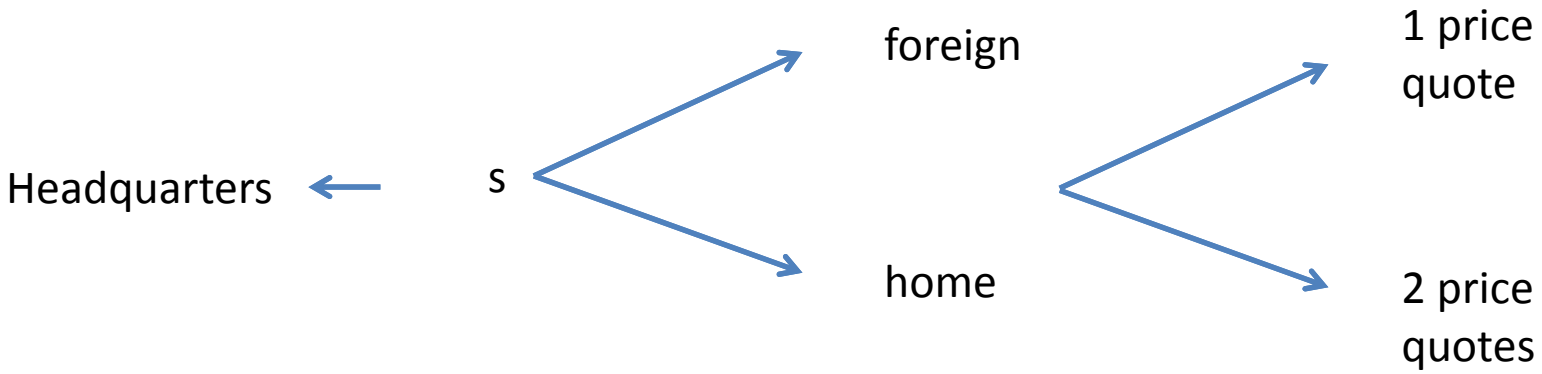
$$p_d = v$$

- Law of one price (no PTM)

$$p_d = x p_d^*$$

# Consumer/Retailer Search Model

- Final good producers (retailers) send a measure s ($s_f$, $s_h$) to find intermediate goods at fixed cost proportional to s
- Each 's' can bring only 1 good from home or foreign mkt
- Each gets one price quote with probability q and two at 1-q
- Producers → Bertrand or monopolistic (but don't know it)
  - a la Burdett-Judd pricing: *randomization on closed interval*



# Key Trade-offs Pinning Down Prices

- Headquarters indifferent between buying or sending more searchers to a given country
  - Pins down the upper bound of distribution
- Trade-off between selling the good and making money on it (markup)
  - Pins down distribution and lower bound

# Implications for PTM

- Prices depend on markup that is local

$$p_x = v + \frac{\theta q}{1-q} x v^* \qquad\qquad p_d = v + \frac{\theta q}{1-q} v$$

- Implies theory needs high markups to generate PTM

$$PT \equiv \frac{\partial \log(p_x)}{\partial \log(x)} = \frac{\frac{\theta q}{1-q}\frac{v^* x}{v}}{1 + \frac{\theta q}{1-q}\frac{x v^*}{v}}|_{ss} = \frac{\frac{\theta q}{1-q}}{1 + \frac{\theta q}{1-q}}$$

- How high?
  - Producer MkUp=30% → PT 24%
  - Producer MkUp=50% → PT 33%
  - Producer MkUp=100% → PT 50%

# Costly Distribution Model

- Sectoral aggregation of differentiated varieties

$$d = \left[\int_0^1 d^h(j)^{\frac{\varphi-1}{\varphi}} dj\right]^{\frac{\varphi}{\varphi-1}}, \quad f = \left[\int_0^1 f^h(j)^{\frac{\varphi-1}{\varphi}} dj\right]^{\frac{\varphi}{\varphi-1}}$$

- Fixed additive cost of distribution $\xi$ → time-varying elasticity faced by monopolistic producers → time-varying markups

$$d(i) = \left(\frac{p_d(i,s^t) + \xi v(s^t)}{P_d}\right)^{-\theta} d, \quad f(i) = \left(\frac{p_f(i) + \xi v}{P_f}\right)^{-\theta} f$$

# Implications for PTM

- Sensitive to micro structure how distribution cost is introduced (need Leontief or close to Leontief)
  - Only elasticity < 1 works (authors assume Leontief – which is the most favorable assumption for the model)
    - Reasonable but not a prevalent feature of all models featuring a distribution sector (e.g. Eaton-Kortum model assume elasticity 1 – and then it does not work)
- Qualitatively same implications as consumer search, but quantitatively performs worse (needs even higher markups)

$$PT \equiv \frac{\partial \log(p_x)}{\partial \log(x)} = \frac{\frac{\xi}{\theta-1}\frac{xv^*}{v}}{1+\frac{\xi}{\theta-1}\frac{xv^*}{v}}|_{ss} = \frac{\frac{\xi}{\theta-1}}{1+\frac{\xi}{\theta-1}}$$

  - REASON: Only part of producer markup affects the price

$$\frac{\theta}{\theta-1} \downarrow + \frac{\xi}{\theta-1}$$

# Industry Aggregation Model

- 'D' and 'F' perfect substitutes in final good aggregator G

$$c + i = \left[ \int_0^1 y(j)^{1-\frac{1}{\gamma}} dj \right]^{\frac{\gamma}{\gamma-1}}$$

- Monopolistic competition on industry level (firm level)

$$y(j) = \left[ \sum_{k=1}^{n} (d(k,j))^{\frac{\rho-1}{\rho}} + \sum_{k=n+1}^{n_X} (f(k,j))^{\frac{\rho-1}{\rho}} \right]^{\frac{\rho}{\rho-1}}$$

  - Key feature: Different elasticity of aggregation on sectoral level

Country 1

Country 2

$u(c)$

Final / consumer level

$c + i = G(\text{“}D\text{”}, \text{“}F\text{”})$

substitutes

Sectoral level

$D \leftarrow \text{“}d\text{”} \quad F \leftarrow \text{“}f\text{”}$

Home and foreign varieties produce by monopolistic producers

Industry level

$\text{“}d\text{”} \leftarrow zF(k, l)$

Potentially heterogeneity of productivity

Asset trade

$x = \frac{u_c^*}{u_c}$

**No trade in goods on the upper levels of aggregation**

Trade in intermediate goods

Fixed entry cost of exporting (+ variable)

$u(c^*)$

$c^* + i^* = G(\text{“}F^*\text{”}, \text{“}D^*\text{”})$

$D^* \leftarrow \text{“}d\text{”} \quad F^* \leftarrow \text{“}f\text{”}$

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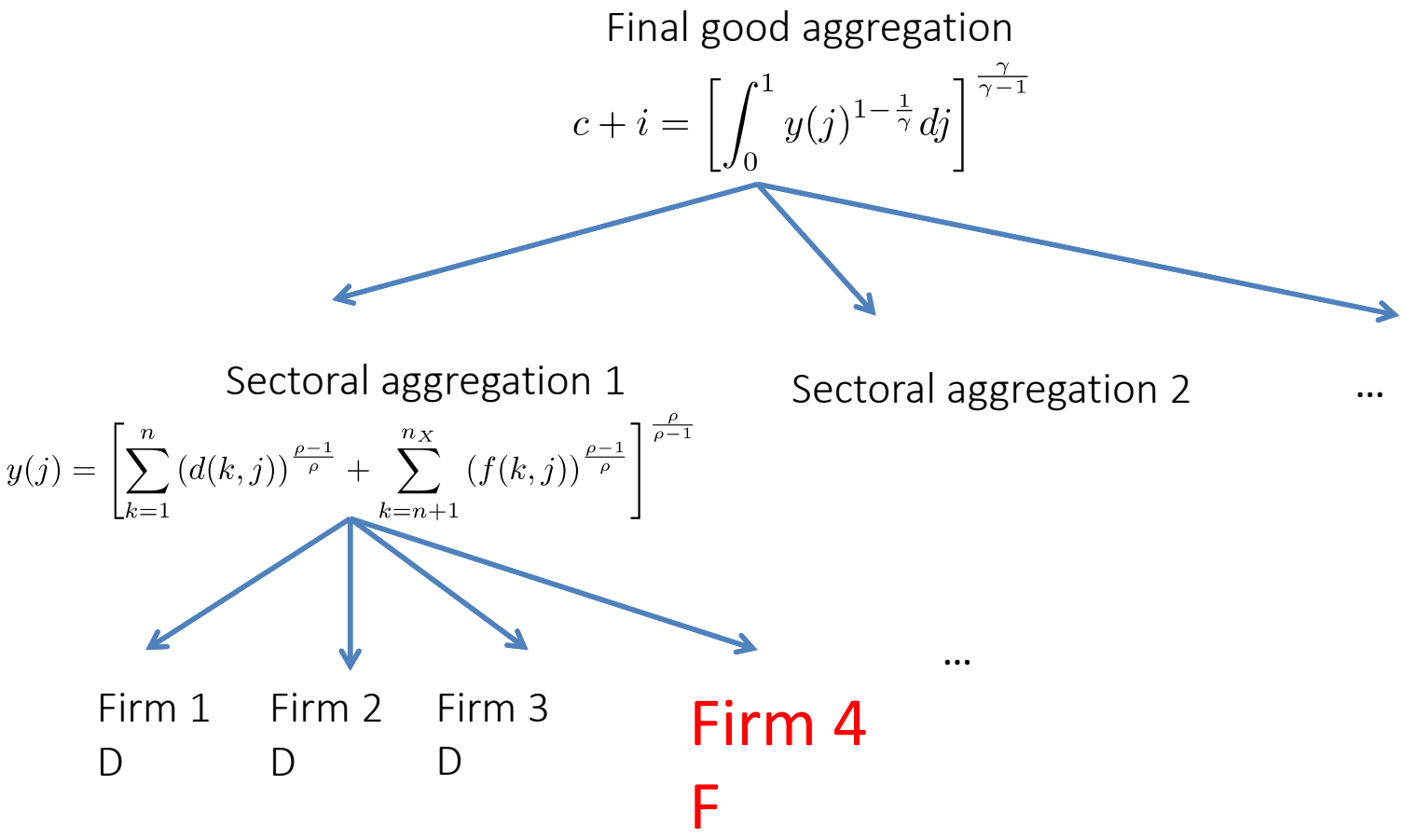
# Industry Aggregation Model



# Key Assumption

- Intermediate goods closer substitutes than sectoral goods, i.e.

$$\gamma > \rho$$

  - Following Dornbusch (1985), implies market shares of firms matter for *the perceived demand elasticity*
    - always part of the low sectoral elasticity is perceived by firms, but how much depends on their market–share

# Prices

- Monopolistic exporters factor in their market share

$$p_x \equiv xP_d^* = \frac{\varepsilon_d^*}{\varepsilon_d^* - 1}(1+\tau)\,v$$

where

$$\varepsilon = \left[\frac{1}{\rho}(1 - S_d^*) + \frac{1}{\gamma}S_d^*\right]^{-1}$$

$$S_d^* = \frac{P_d^* d^*}{nP_f^* f^* + n_X P_d^* d^*}$$

- Due to fixed cost of entry exporters are bigger but there are fewer of them, leading to PTM (a nice point that AB make)

# Implications for PTM

- Variation of markups on exported goods determined by

$$\frac{d\log(\frac{p_x}{v})}{d\log(S_d^*)} = \frac{S_d^*\left(\frac{1}{\gamma}-\frac{1}{\rho}\right)}{1-\frac{1}{\rho}(1-S_d^*)-\frac{1}{\gamma}S_d^*}.$$

- Hence, change in market-share S drives PTM
  - Key point: after a shock, S abroad changes more than at home due to home-bias and firm size differences (fixed cost of exporting)

# Implications for PTM

- Model requires sizable movements of market shares:
  - Suppose we want to match PT=35%
  - How volatile market shares must be?
    - Best case scenario: one firm services all exports (assume this), elasticity as in AB: 8.7, and 1.5; recover std(S) from

$$PT \equiv \frac{d\log p_x}{d\log x} = \left.\frac{S_d^*\left(\frac{1}{\gamma}-\frac{1}{\rho}\right)}{1-\frac{1}{\rho}\left(1-S_d^*\right)-\frac{1}{\gamma}S_d^*}\right|_{ss} \frac{d\log \hat{S}_d^*}{d\log x}$$

    - Implies S is 1.8x as volatile as x-rate, in data 1.2x (US)
      - factoring in the VERY low correlation of S and x and favorable assumptions we made for the model, this is too much
- Model requires home and foreign goods must be close substitutes: which is a problem on the quantity side (more about this later)

# Deep Habit Model

- Sectoral aggregation

$$d = \left[ \int_0^1 d^h(j)^{\frac{\varphi-1}{\varphi}} dj \right]^{\frac{\varphi}{\varphi-1}}, \quad f = \left[ \int_0^1 f^h(j)^{\frac{\varphi-1}{\varphi}} dj \right]^{\frac{\varphi}{\varphi-1}}$$

- where ($\theta$ negative)

$$d^h(j) = \frac{D(j)}{h_d(j)^{\theta}}$$

- Habit formation through sales (deep habit)

$$h_d(j,t) = \rho h_d(j,t-1) + (1-\rho)\bar{D}(j,t)$$

# Deep Habit Model

- Monopolistic producers face dynamic demand

$$D\left(i,t\right)=\left(\frac{p_d\left(i,t\right)}{P_d\left(t\right)}\right)^{-\varphi}h_d\left(i,t-1\right)^{\theta(1-\varphi)}d$$

- Results in export prices that are Dixit-Stiglitz *less* shadow value of extra habit

$$xp_d=\frac{\phi}{\phi-1}\left[v-(1-\rho)\psi_d^*\right]$$

where

$$\Delta_d^*=\frac{xp_d^*}{\phi}$$

Cost of selling output with no habit (loss of markup)

$$\psi_d^*=EQ\left[\rho\psi_{d,t+1}^*+\Delta_{d,t+1}^*\frac{\theta\left(1-\varphi\right)D^*\left(j,t+1\right)}{h_d^*\left(i,t\right)}\right]$$

# Implications for PTM

- After persistent p. shock value of habit increases and x depreciates

$$xp_d = \frac{\phi}{\phi - 1}\left[v - (1-\rho)\psi_d^*\right]$$

where

$$\Delta_d^* = \frac{xp_d^*}{\phi}$$ → Cost of selling output with no habit (loss of markup)

$$\psi_d^* = EQ\left[\rho\psi_{d,t+1}^* + \Delta_{d,t+1}^* \frac{\theta\left(1-\varphi\right)D^*\left(j,t+1\right)}{h_d^*\left(i,t\right)}\right]$$ → value of habit

- Has exactly opposite predictions for prices* to what we want
  - *Ravn et al. show that for a special type of government shocks this result can be overturned, but does not work for usual shocks

# The Essence of the Problem

- Habit is accumulated by slashing markups:
  - real exchange rate depreciations generated by usual shocks make times of depreciations times when firms want to accumulate more habit for the future

# Quantitative Evaluation

- Calibration
  - Import share for US 12%
  - Standard international elasticity 1.5 (with exception of industry aggregation model – values from AB used)
  - 30% producer markups (rather on high side in macro lit.)
  - 30% work hours relative to time endowment
  - Standard parameters and productivity shocks
- When applicable
  - Distribution sector of 50%
  - Non-tradable sector calibrated to STAN shares and distinct shocks from data in tradable and non-tradable sector

# Moments for prices

- Analyze moments pertaining to decomposition

$$p_x \equiv \frac{P_X}{P} = \underbrace{\frac{P_X}{P_D}}_{p_d^x} \times \underbrace{\frac{P_D}{P}}_{p_d},$$

Table 2: Moments summarizing deviations from LOP.

| Statistic | Description |
|---|---|
| $\sigma(p_d^x)/\sigma(x)$ | Relative magnitude of deviations from LOP |
| $\sigma(p_d)/\sigma(x)$ | Relative volatility of the price of tradable goods at home |
| $\rho(p_d^x, x)$ | Correlation of dev. from LOP w/ the real exchange rate |
| $\rho(p_d, x)$ | Correlation of home prices w/ the real exchange rate |

$\sigma$ denotes the standard deviation of logged and HP filtered data; $\rho$ denotes the correlation coefficient.

# Aggregate Data for US

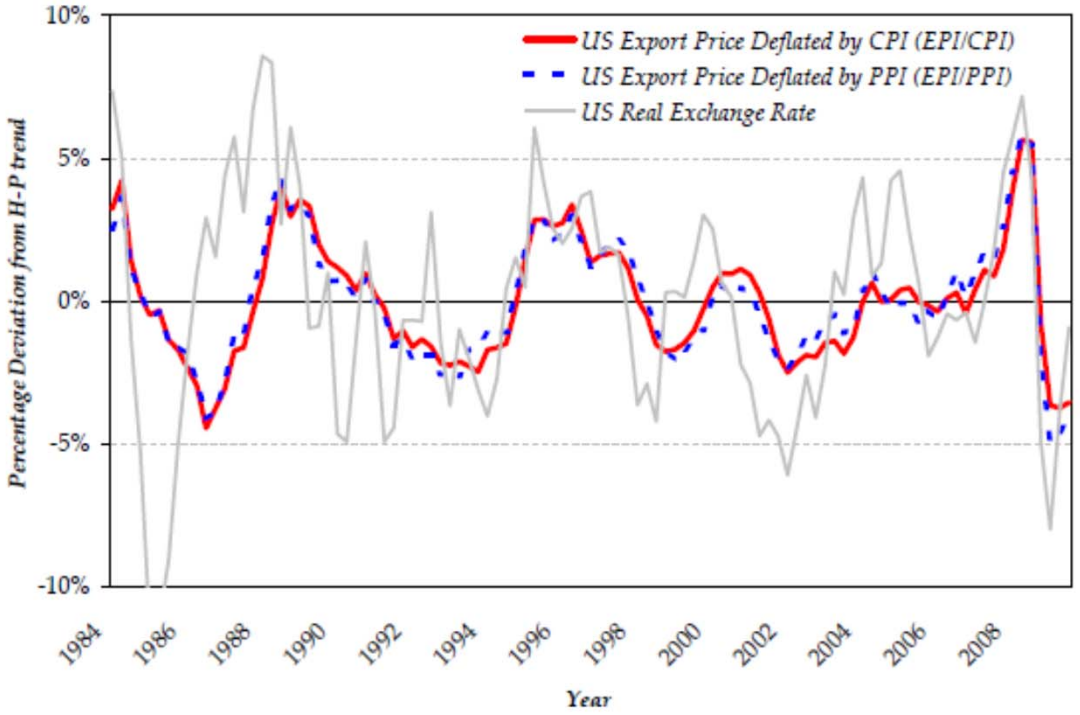



Figure 1: Dynamics of Aggregate Export Price in the US.

# Aggregate Data for US

Table 3: Deviations from LOP in Aggregate Data.

| Statistic | Value |
|---|---|
| *A. Properties of Aggregate Real Export Price* | |
| $\sigma(p_x)/\sigma(x)$ | .52 |
| $\rho(p_x, x)$ | .47 |
| *B. Deviations from LOP* | |
| $\sigma(p_d^x)/\sigma(x)$ | .53 |
| $\rho(p_d^x, x)$ | .51 |
| *C. Residual* | |
| $\sigma(p_d)/\sigma(x)$ | .13 |
| $\rho(p_d, x)$ | -.18 |

$\sigma$ denotes the standard deviation of logged and HP filtered data, $\rho$ denotes the correlation coefficient.

# Disaggregated Data: Example for Japan

Table 4: Deviations from LOP in Disaggregated Data.

| Statistics | Median Value | Quartile bracket $[Q_1, Q_3]$ |
|---|---|---|
| *A. Properties of disaggregated real export prices* | | |
| $\sigma(p_{x,i})/\sigma(x)$ | .88 | [ .54, .99 ] |
| $\rho(p_{x,i}, x)$ | .82 | [ .50, .89 ] |
| *B. Deviations from LOP* | | |
| $\sigma(p^x_{d,i})/\sigma(x)$ | .90 | [ .55, .99 ] |
| $\rho(p^x_{d,i}, x)$ | .84 | [ .67, .89 ] |
| *C. Residual* | | |
| $\sigma(p_{d,i})/\sigma(x)$ | .23 | [ .11, .33 ] |
| $\rho(p_{d,i}, x)$ | -.14 | [-.25, .07 ] |

$\sigma$ denotes the standard deviation of logged and HP filtered data, $\rho$ denotes the correlation coefficient.

# Prices

Table 5: International Prices: Comovement and Relative Volatility[a]

| | | Predictions of the PTM Theories | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Statistic | Data[b] | Frictionless Model | Consumer Search | Consumer Search* | Costly Distribution | Costly Distribution*[d] | Industry Aggregation | Deep Habits |
| *A. Correlations* | | | | | | | | |
| $p_x, x$ | 0.47 | -1.00 | 1.00 | 0.82 | 1.00 | 0.52 | 0.98 | -0.95 |
| $p_d^x, x$ | 0.51 | 0.02 | 1.00 | 0.98 | 1.00 | 0.98 | 1.00 | -0.83 |
| $p_d, x$ | -0.18 | -1.00 | -1.00 | 0.11 | -1.00 | 0.27 | -1.00 | -0.97 |
| *B. Standard deviations* | | | | | | | | |
| $x$ | 3.97 | 0.45 | 0.55 | 3.67 | 0.54 | 1.86 | 0.31 | 0.51 |
| *relative to*[c] $x$ | | | | | | | | |
| $p_x$ | 0.52 | 0.16 | 0.18 | 0.26 | 0.04 | 0.83 | 0.23 | 0.36 |
| $p_d^x$ | 0.53 | 0.00 | 0.30 | 0.20 | 0.17 | 0.24 | 0.35 | 0.12 |
| $p_d$ | 0.13 | 0.16 | 0.12 | 0.14 | 0.13 | 0.76 | 0.11 | 0.17 |
| *C. X-Rate Pass-through* | | | | | | | | |
| | 35%-50% | 0% | 23% | 18% | 15% | 20% | 40% | <0 |
| *D. Producer Markups* | | | | | | | | |
| | 30% | 0% | 30% | 22% | 30% | 40% | 30% | 30% |

[a]All reported statistics are based on logged and Hodrick-Prescott filtered quarterly time series (with a smoothing parameter $\lambda = 1600$).
[b]Data for the US, 1981:1-2009:4.
[c]Ratio of corresponding standard deviation to the standard deviation of the real exchange rate $x$.
[d]The model has been calibrated to annual frequency and the statistics generated are not readily comparable to the ones listed in data column.

# Prices: Some Other Issues

- Consumer search* has labor wedge shocks – without this shock international correlation of employment is negative
- Industry aggregation with non-tradable goods has counterfactual predictions about volatility of tradable to non-tradable price relative to x-rate – helps get PTM…
- Industry aggregation assumes best case scenario of exporter size

# Quantities

Table 6: Quantities - Comovement and Relative Volatility[a]

| | | Predictions of the PTM Theories | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Statistic | Data[b] | Frictionless Model | Consumer Search | Consumer Search* | Costly Distribution | Costly Distribution*[d] | Industry Aggregation | Deep Habits |
| *A. Correlations* | | | | | | | | |
| *domestic with foreign* | | | | | | | | |
| *Measured* TFP[c] | 0.30 | 0.30 | 0.34 | 0.44 | 0.33 | 0.54 | 0.31 | 0.30 |
| GDP | 0.40 | 0.36 | 0.40 | 0.50 | 0.38 | 0.56 | 0.17 | 0.37 |
| Consumption | 0.25 | 0.33 | 0.30 | 0.61 | 0.32 | 0.54 | 0.73 | 0.40 |
| Employment | 0.21 | 0.49 | 0.52 | 0.43 | 0.50 | 0.55 | 0.05 | 0.55 |
| Investment | 0.23 | 0.19 | 0.24 | 0.56 | 0.23 | 0.31 | 0.32 | 0.26 |
| *GDP with* | | | | | | | | |
| Consumption | 0.83 | 0.95 | 0.95 | 1.00 | 0.96 | 0.99 | 0.94 | 0.95 |
| Employment | 0.85 | 0.98 | 0.98 | 0.96 | 0.98 | 0.91 | 0.99 | 0.97 |
| Investment | 0.93 | 0.67 | 0.67 | 0.73 | 0.67 | 0.45 | 0.64 | 0.67 |
| Net exports | -0.49 | -0.57 | -0.54 | -0.49 | -0.56 | -0.87 | 0.58 | -0.56 |
| *Terms of trade with* | | | | | | | | |
| Net exports | -0.17 | -0.84 | -0.86 | -0.86 | -0.86 | -0.77 | 0.98 | -0.93 |
| *B. Standard deviations* | | | | | | | | |
| GDP | 1.33 | 1.13 | 1.18 | 2.45 | 1.15 | 2.05 | 1.55 | 1.08 |
| *relative to GDP*[d] | | | | | | | | |
| *Measured* TFP | 0.60 | 0.70 | 0.67 | 0.32 | 0.69 | 0.89 | 0.51 | 0.74 |
| Consumption | 0.74 | 0.33 | 0.36 | 0.84 | 0.36 | 0.78 | 0.44 | 0.38 |
| Investment | 2.79 | 3.24 | 3.76 | 2.76 | 3.77 | 3.00 | 2.78 | 3.81 |
| Employment | 0.81 | 0.47 | 0.50 | 1.30 | 0.47 | 0.17 | 0.75 | 0.41 |
| Net exports | 0.30 | 0.14 | 0.13 | 0.04 | 0.13 | 0.11 | 0.21 | 0.13 |

[a] All reported statistics are based on logged and Hodrick-Prescott filtered quarterly time series (with a smoothing parameter $\lambda = 1600$).
[b] US data for the period 1980:1-2004:1.
[c] Calculated using the actual national accounting formulas; due to time varying markups measured TFP slightly differs from the TFP coefficient fed into the models.
[d] Ratio of corresponding standard deviation to the standard deviation of *GDP*.
[e] The model has been calibrated to annual frequency and the statistics generated are not readily comparable to the ones listed in data column.

# Conclusions

- PTM can bring relative international prices closer to data under some conditions
- But…
  - Leading theories do not universally work the same way in all contexts and impose some limitations that may be problem in specific applications
    - Our paper characterizes these restrictions / limitations