Currency Choice and Exchange Rate Pass-through

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Motivation

• Most NOEM papers assume **exogenous** currency choice:
  – PCP as originally in Obstfeld and Rogoff (1995)
  – LCP as in Betts and Devereux (2000)
  – both LCP and PCP as in Devereux and Engel (2003)

• This has immediate implications for short-run and long-run pass-through, as well as for **optimal policy**
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• This has immediate implications for short-run and long-run pass-through, as well as for *optimal policy*

• When currency of pricing is chosen *endogenously*, pass-through and currency choice are tightly interrelated

• We study both empirically and theoretically this link between exchange rate pass-through and optimal currency choice
Main Findings

- Pass-through is very different for LCP and PCP firms:
  - at a 2 year horizons at the aggregate: 0.15 vs. 0.95
  - conditional on price adjustment: 0.25 vs. 0.95
  - conditional on multiple price adjustments: 0.50 vs. 0.95

- This is evidence of endogenous currency choice and substantial ‘real rigidities’
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• We extend Engel’s (2006) equivalence result to a dynamic sticky price environment:
  • Sufficient statistic: Medium-run Pass-through
  • MRPT can be estimated empirically from observed prices
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- The data strongly support endogenous currency choice theory
Outline

1 Data

2 Empirical Facts
   - Aggregate Evidence
   - Micro-level Evidence
   - Additional Facts
   - Life-long Pass-through

3 Currency and Prices: Model
   - Analytical Model
   - Structural Model
   - Estimation of MRPT
   - Numerical Simulation

4 Discussion
Dataset

- Unpublished BLS micro data on prices at the dock of imports and exports for the U.S. (Gopinath and Rigobon, 2008)

- Monthly transaction prices for 55k imported items, period 1994-2004

- Currency Information:
  - Firms report the price and the currency of pricing
  - Prices are sticky in the reported currency (11 months)
  - Over 90% of import items priced in dollars with large variation across countries
Our Sample

- Market transactions only
- 12 countries with $>10$ and $>5\%$ of non-dollar items
Our Sample

- Market transactions only
- 12 countries with >10 and >5% of non-dollar items

<table>
<thead>
<tr>
<th>Country</th>
<th>% Non-$</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Germany</td>
<td>0.40</td>
<td>1,156</td>
</tr>
<tr>
<td>Switzerland</td>
<td>0.38</td>
<td>220</td>
</tr>
<tr>
<td>Italy</td>
<td>0.22</td>
<td>1,112</td>
</tr>
<tr>
<td>Japan</td>
<td>0.21</td>
<td>2,553</td>
</tr>
<tr>
<td>UK</td>
<td>0.19</td>
<td>719</td>
</tr>
<tr>
<td>Belgium</td>
<td>0.17</td>
<td>122</td>
</tr>
<tr>
<td>France</td>
<td>0.13</td>
<td>582</td>
</tr>
<tr>
<td>Sweden</td>
<td>0.12</td>
<td>181</td>
</tr>
<tr>
<td>Spain</td>
<td>0.11</td>
<td>261</td>
</tr>
<tr>
<td>Netherlands</td>
<td>0.10</td>
<td>148</td>
</tr>
<tr>
<td>Austria</td>
<td>0.10</td>
<td>93</td>
</tr>
<tr>
<td>Canada</td>
<td>0.04</td>
<td>1,906</td>
</tr>
</tbody>
</table>
Figure: Conventional Measure of ERPT at different horizons $T$:

$$\Delta p_t = a + \sum_{\tau=0}^{T} b_{\tau} \Delta e_{t-\tau} + z_t' \gamma + \varepsilon_t \rightarrow \beta_T \equiv \sum_{\tau=0}^{T} b_{\tau}$$
Aggregate ERPT: splitting by Currency

Figure: ERPT at different horizons by currency of pricing:

\[ \Delta p^c_t = a^c + \sum_{\tau=0}^{T} b^c_{\tau} \Delta e_{t-\tau} + z'_t \gamma^c + \varepsilon_t, \quad c \in \{\$,€\} \]
\[ \Delta p_{i,t}^c = a_i^c + \sum_{\tau=0}^{T} b_{i,\tau}^c \Delta e_{i,t-\tau} + z_{it}' \delta_i^c + \varepsilon_{it}^c \]
By country

Figure: ERPT at different horizons by country and currency:

$$\Delta p_{i,t}^c = a_i^c + \sum_{\tau=0}^{T} b_{i,\tau}^c \Delta e_{i,t-\tau} + z_{it}^\prime \delta_i^c + \varepsilon_{it}^c$$
Micro-level Evidence

- Pass-through Conditional on Price Adjustment

$$\Delta \bar{p}_{i,t} = \left[ \beta_D \cdot D_i + \beta_{ND} \cdot (1 - D_i) \right] \cdot \Delta c e_{i,t} + Z'_{i,t} \gamma + \epsilon_{i,t}$$
Pass-through Cond’l on Price Adjustment

Differentiated Goods

<table>
<thead>
<tr>
<th></th>
<th>Dollar</th>
<th>Non-Dollar</th>
<th>Difference</th>
<th>(N_g)</th>
<th>(R^2)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(\beta_D)</td>
<td>s.e.((\beta_D))</td>
<td>(\beta_{ND})</td>
<td>s.e.((\beta_{ND}))</td>
<td>(\beta_{ND} - \beta_D)</td>
</tr>
<tr>
<td>All Countries</td>
<td>0.24</td>
<td>0.04</td>
<td>0.96</td>
<td>0.06</td>
<td>0.72</td>
</tr>
<tr>
<td>Germany</td>
<td>0.44</td>
<td>0.10</td>
<td>0.92</td>
<td>0.12</td>
<td>0.48</td>
</tr>
<tr>
<td>Switzerland</td>
<td>0.10</td>
<td>0.15</td>
<td>0.99</td>
<td>0.31</td>
<td>0.89</td>
</tr>
<tr>
<td>Italy</td>
<td>0.23</td>
<td>0.08</td>
<td>0.81</td>
<td>0.10</td>
<td>0.58</td>
</tr>
<tr>
<td>Japan</td>
<td>0.19</td>
<td>0.04</td>
<td>0.98</td>
<td>0.10</td>
<td>0.81</td>
</tr>
<tr>
<td>UK</td>
<td>0.32</td>
<td>0.19</td>
<td>0.89</td>
<td>0.16</td>
<td>0.56</td>
</tr>
<tr>
<td>Belgium</td>
<td>0.01</td>
<td>0.07</td>
<td>0.98</td>
<td>0.14</td>
<td>0.98</td>
</tr>
<tr>
<td>France</td>
<td>0.29</td>
<td>0.12</td>
<td>1.17</td>
<td>0.14</td>
<td>0.88</td>
</tr>
<tr>
<td>Sweden</td>
<td>0.44</td>
<td>0.15</td>
<td>1.43</td>
<td>0.11</td>
<td>0.99</td>
</tr>
<tr>
<td>Spain</td>
<td>0.53</td>
<td>0.11</td>
<td>0.73</td>
<td>0.15</td>
<td>0.20</td>
</tr>
<tr>
<td>Netherlands</td>
<td>0.17</td>
<td>0.22</td>
<td>1.19</td>
<td>0.03</td>
<td>1.01</td>
</tr>
<tr>
<td>Canada</td>
<td>-0.06</td>
<td>0.12</td>
<td>0.51</td>
<td>1.16</td>
<td>0.57</td>
</tr>
</tbody>
</table>

\[
\Delta \bar{p}_{i,t} = [\beta_D \cdot D_i + \beta_{ND} \cdot (1 - D_i)] \cdot \Delta c e_{i,t} + Z'_{i,t} \gamma + \epsilon_{i,t}
\]
## Sectoral Evidence
### Pass-through Conditional on Price Adjustment

<table>
<thead>
<tr>
<th>Category</th>
<th>Harm. Code</th>
<th>Dollar</th>
<th>Non-Dollar</th>
<th>Difference</th>
<th>$N_{obs}$</th>
<th>$N_g$</th>
<th>$N_g^{ND}/N_g$</th>
<th>$R^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Live Animals; Animal Products</td>
<td>01-05</td>
<td>0.18</td>
<td>0.16</td>
<td>-0.11</td>
<td>0.53</td>
<td>-0.28</td>
<td>0.53</td>
<td>1,841</td>
</tr>
<tr>
<td>Vegetable Products</td>
<td>06-14</td>
<td>0.04</td>
<td>0.27</td>
<td>1.10</td>
<td>0.10</td>
<td>1.06</td>
<td>4.00</td>
<td>746</td>
</tr>
<tr>
<td>Animal/Vegetable Fats, Oils</td>
<td>15</td>
<td>0.65</td>
<td>0.32</td>
<td>—</td>
<td>—</td>
<td>0.18</td>
<td>0.50</td>
<td>145</td>
</tr>
<tr>
<td>Prepared Foodstuffs</td>
<td>16-24</td>
<td>0.24</td>
<td>0.06</td>
<td>0.83</td>
<td>0.25</td>
<td>0.59</td>
<td>2.27</td>
<td>1,668</td>
</tr>
<tr>
<td>Mineral Products</td>
<td>25-27</td>
<td>0.96</td>
<td>0.19</td>
<td>1.14</td>
<td>0.35</td>
<td>0.18</td>
<td>0.50</td>
<td>4,588</td>
</tr>
<tr>
<td>Products of chemical and allied industries</td>
<td>28-38</td>
<td>0.27</td>
<td>0.08</td>
<td>0.64</td>
<td>0.25</td>
<td>0.37</td>
<td>1.38</td>
<td>2,291</td>
</tr>
<tr>
<td>Plastics/Rubber articles</td>
<td>39-40</td>
<td>0.21</td>
<td>0.07</td>
<td>0.53</td>
<td>0.11</td>
<td>0.32</td>
<td>2.57</td>
<td>896</td>
</tr>
<tr>
<td>Raw Hides/leather articles, furs</td>
<td>41-43</td>
<td>-0.15</td>
<td>0.14</td>
<td>0.91</td>
<td>0.03</td>
<td>1.06</td>
<td>7.40</td>
<td>158</td>
</tr>
<tr>
<td>Wood and articles of wood</td>
<td>44-46</td>
<td>-0.08</td>
<td>0.17</td>
<td>0.85</td>
<td>0.00</td>
<td>0.94</td>
<td>5.39</td>
<td>4,850</td>
</tr>
<tr>
<td>Pulp of wood/other fibrous cellulosic material</td>
<td>47-49</td>
<td>0.26</td>
<td>0.11</td>
<td>1.02</td>
<td>0.20</td>
<td>0.76</td>
<td>2.85</td>
<td>482</td>
</tr>
<tr>
<td>Textile and textile articles</td>
<td>50-63</td>
<td>0.41</td>
<td>0.14</td>
<td>0.94</td>
<td>0.12</td>
<td>0.54</td>
<td>2.85</td>
<td>482</td>
</tr>
<tr>
<td>Footwear, headgear etc.</td>
<td>64-67</td>
<td>0.45</td>
<td>0.16</td>
<td>0.97</td>
<td>0.07</td>
<td>0.52</td>
<td>4.61</td>
<td>161</td>
</tr>
<tr>
<td>Misc. manufactured articles</td>
<td>68-70</td>
<td>0.19</td>
<td>0.17</td>
<td>1.06</td>
<td>0.24</td>
<td>0.87</td>
<td>2.83</td>
<td>460</td>
</tr>
<tr>
<td>Precious or semi-prec. stones</td>
<td>71</td>
<td>0.24</td>
<td>0.13</td>
<td>2.03</td>
<td>0.74</td>
<td>1.79</td>
<td>2.48</td>
<td>1,882</td>
</tr>
<tr>
<td>Base metals and articles of base metals</td>
<td>72-83</td>
<td>0.21</td>
<td>0.04</td>
<td>1.35</td>
<td>0.36</td>
<td>1.15</td>
<td>3.19</td>
<td>3,693</td>
</tr>
<tr>
<td>Machinery and mechanical appliances etc.</td>
<td>84-85</td>
<td>0.22</td>
<td>0.05</td>
<td>0.90</td>
<td>0.06</td>
<td>0.67</td>
<td>9.51</td>
<td>5,943</td>
</tr>
<tr>
<td>Vehicles, aircraft etc.</td>
<td>86-89</td>
<td>0.17</td>
<td>0.07</td>
<td>0.93</td>
<td>0.10</td>
<td>0.76</td>
<td>6.31</td>
<td>2,337</td>
</tr>
<tr>
<td>Optical, photographic etc.</td>
<td>90-92</td>
<td>0.22</td>
<td>0.07</td>
<td>1.09</td>
<td>0.20</td>
<td>0.88</td>
<td>4.18</td>
<td>928</td>
</tr>
<tr>
<td>Arms and ammunition</td>
<td>93</td>
<td>0.08</td>
<td>0.16</td>
<td>1.03</td>
<td>0.09</td>
<td>0.95</td>
<td>5.00</td>
<td>109</td>
</tr>
<tr>
<td>Articles of stone, plaster etc.</td>
<td>94-96</td>
<td>0.54</td>
<td>0.09</td>
<td>0.76</td>
<td>0.12</td>
<td>0.23</td>
<td>1.53</td>
<td>394</td>
</tr>
</tbody>
</table>
Additional Facts

• 10-digit sectors with a mix of Dollar and Non-Dollar pricers:
  — 0.30 versus 0.95

• 125 goods that changed currency of invoicing:
  — 0.50 versus 1.18

• Exports: Dollar (PCP, 97%) and Non-Dollar (LCP, 3%)
  — 0.84 versus 0.25

• Frequency: Dollar versus Non-Dollar
  — All: 0.10 versus 0.07
  — 6-digit: 0.14 versus 0.08
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Life-long Pass-through

\[ \Delta L \bar{p}_{i,T} = \left[ \beta^L_D \cdot D_i + \beta^L_{ND} \cdot (1 - D_i) \right] \cdot \Delta L e_{i,T} + Z'_{i,T} \gamma + \epsilon_{i,t} \]
Life-long Pass-through

\[
\Delta_L \bar{\rho}_{i,T} = [\beta^L_D \cdot D_i + \beta^L_{ND} \cdot (1 - D_i)] \cdot \Delta_L e_{i,T} + Z'_{i,T} \gamma + \epsilon_{i,t}
\]
Currency and Prices
in a Dynamic Sticky Price Model

- Multi-period sticky price model
- A firm chooses currency of pricing when it adjusts its price
- Exogenous frequency of price adjustment (Calvo)
- Partial equilibrium: single firm’s problem
  - exchange rate process is exogenous
  - price level dynamics is exogenous
- General result linking currency choice with pass-through independently of their primitive determinants
Currency and Prices
in a Dynamic Sticky Price Model

**Primitive Parameters:**
- Curvature of Demand
- Returns to Scale
- Importance of Local Costs

**Desired Pass-Through**

**Currency Choice:**
LCP vs. PCP
Price Setting

- Desired Price:

\[ \tilde{p}(s_t) = \arg \max_p \Pi(p|s_t), \quad \tilde{p}_t^* = \tilde{p}_t - e_t \]
Price Setting

- Desired Price:
  \[ \tilde{p}(s_t) = \arg \max_p \Pi(p|s_t), \quad \tilde{p}_t^* = \tilde{p}_t - e_t \]

- Local Currency Pricing:
  \[ V_L(p|s^t) = \Pi(p|s^t) + \delta \theta \mathbb{E}_t V_L(p|s^{t+1}) + \delta (1 - \theta) \mathbb{E}_t V(s^{t+1}) \]
  \[ \tilde{p}_L(s^t) = \arg \max_p V_L(p|s^t) \]
Price Setting

- **Desired Price:**

\[
\tilde{p}(s_t) = \arg \max_p \Pi(p|s_t), \quad \tilde{p}_t^* = \tilde{p}_t - e_t
\]

- **Local Currency Pricing:**

\[
V_L(p|s^t) = \Pi(p|s_t) + \delta \theta \mathbb{E}_t V_L(p|s^{t+1}) + \delta (1 - \theta) \mathbb{E}_t V(s^{t+1})
\]

\[
\bar{p}_L(s^t) = \arg \max_p V_L(p|s^t)
\]

- **Producer Currency Pricing:**

\[
V_P(p^*|s^t) = \Pi(p^* + e_t|s_t) + \delta \theta \mathbb{E}_t V_P(p^*|s^{t+1}) + \delta (1 - \theta) \mathbb{E}_t V(s^{t+1})
\]

\[
\bar{p}_P^*(s^t) = \arg \max_p V_P(p^*|s^t)
\]
Price Setting

• Desired Price:
  \[ \tilde{p}(s_t) = \arg \max_p \Pi(p|s_t), \quad \tilde{p}_t^* = \tilde{p}_t - e_t \]

• Local Currency Pricing:
  \[ V_L(p|s_t) = \Pi(p|s_t) + \delta \theta \mathbb{E}_t V_L(p|s_{t+1}) + \delta (1 - \theta) \mathbb{E}_t V(s_{t+1}) \]
  \[ \bar{p}_L(s_t) = \arg \max_p V_L(p|s_t) \]

• Producer Currency Pricing:
  \[ V_P(p^*|s_t) = \Pi(p^* + e_t|s_t) + \delta \theta \mathbb{E}_t V_P(p^*|s_{t+1}) + \delta (1 - \theta) \mathbb{E}_t V(s_{t+1}) \]
  \[ \bar{p}_P(s_t) = \arg \max_p V_P(p^*|s_t) \]

• Currency Choice:
  \[ V(s_t) = \max \{ V_L(\bar{p}_L(s_t)|s_t), V_P(\bar{p}_P^*(s_t)|s_t) \} \]
Optimal Price Setting

Equivalence Result

Proposition

The first order approximation to optimal price setting in local and producer currency is given respectively by:

\[
\bar{p}_L(s^t) = (1 - \delta \theta) \sum_{\ell=0}^{\infty} (\delta \theta)^{\ell} \mathbb{E}_t \tilde{p}(s_{t+\ell}),
\]

\[
\bar{p}_P^*(s^t) = (1 - \delta \theta) \sum_{\ell=0}^{\infty} (\delta \theta)^{\ell} \mathbb{E}_t \{ \tilde{p}(s_{t+\ell}) - e_{t+\ell} \},
\]

which implies the following equivalence between optimal prices in the local and producer currency:

\[
\bar{p}_L(s^t) = \bar{p}_P^*(s^t) + e_t.
\]

⇒ Pass-through is the same conditional on price adjustment
Currency Choice

- Value Differential between LCP and PCP:

\[
\mathcal{L}(s^t) = V_L(\bar{p}_L(s^t)|s^t) - V_P(\bar{p}_P^*(s^t)|s^t)
= \sum_{\ell=0}^{\infty} (\delta \theta)^{\ell} \mathbb{E}_t \{ \Pi(\bar{p}_L(s^t)|s_{t+\ell}) - \Pi(\bar{p}_P^*(s^t) + e_{t+\ell}|s_{t+\ell}) \}
\]
Currency Choice

- Value Differential between LCP and PCP:

\[
\mathcal{L}(s^t) = V_L(\bar{p}_L(s^t)|s^t) - V_P(\bar{p}_P^*(s^t)|s^t) = \sum_{\ell=0}^{\infty} (\delta\theta)^\ell \mathbb{E}_t \left\{ \Pi(\bar{p}_L(s^t)|s_{t+\ell}) - \Pi(\bar{p}_P^*(s^t) + e_{t+\ell}|s_{t+\ell}) \right\}
\]

Proposition

The second order approximation to \( \mathcal{L}(s^t) \):

\[
\mathcal{L}(s^t) = K(s^t) \sum_{\ell=0}^{\infty} (\delta\theta)^\ell \text{var}_t(e_{t+\ell}) \left[ \frac{1}{2} - \frac{\text{cov}_t(\bar{p}(s_{t+\ell}), e_{t+\ell})}{\text{var}_t(e_{t+\ell})} \right],
\]

Therefore, the firm chooses LCP when

\[
\bar{\Psi} \equiv (1 - \delta\theta)^2 \sum_{\ell=1}^{\infty} (\delta\theta)^{\ell-1} \ell \frac{\text{cov}_t(\bar{p}(s_{t+\ell}), e_{t+\ell})}{\text{var}_t(e_{t+\ell})} < \frac{1}{2}
\]

and PCP otherwise.
Medium-run Pass-through

- General Expression:

\[
\bar{\Psi} = (1 - \delta \theta) \sum_{j=0}^{\infty} (\delta \theta)^j \left[ (1 - \delta \theta) \sum_{\ell=1}^{\infty} (\delta \theta)^{\ell-1} \tilde{\Psi}_{\ell,\ell+j}(s^t) \right],
\]

where

\[
\tilde{\Psi}_{j,\ell}(s^t) \equiv \frac{\text{cov}_t(\tilde{p}(s_{t+\ell}), \Delta e_{t+j})}{\text{var}_t(\Delta e_{t+j})}
\]
Medium-run Pass-through

• General Expression:

\[ \Psi = (1 - \delta \theta) \sum_{j=0}^{\infty} (\delta \theta)^j \left[ (1 - \delta \theta) \sum_{\ell=1}^{\infty} (\delta \theta)^{\ell-1} \tilde{\Psi}_{\ell,\ell+j}(s^t) \right], \]

where

\[ \tilde{\Psi}_{j,\ell}(s^t) = \frac{\text{cov}_t(\tilde{p}(s_{t+\ell}), \Delta e_{t+j})}{\text{var}_t(\Delta e_{t+j})} \]

• Special Case: \( \tilde{\Psi}_{\ell,\ell+j}(s^t) = \tilde{\Psi}_j \)

\[ \Psi = (1 - \delta \theta) \sum_{j=0}^{\infty} (\delta \theta)^j \tilde{\Psi}_j \]
Desired Price:

\[ \tilde{p}_t \equiv \tilde{p}(e_t, P_t | z_t) = \mu(\tilde{p}_t - P_t | z_t) + mc^*(e_t | z_t) + e_t \]

Denote:

\[ \phi_t \equiv \frac{\partial [mc_t^* + e_t]}{\partial e_t} \quad \text{and} \quad \Gamma_t \equiv -\frac{\partial \mu_t}{\partial (p_t - P_t)} \]
Structure Model
of Incomplete Pass-through

• Desired Price:

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Proposition

Let \( \phi \) and \( \Gamma \) be constant. Then

\[ \tilde{\Psi}_{\ell, \ell+j}(s^t) = \tilde{\Psi}_j = \frac{\phi}{1 + \Gamma} + \frac{\Gamma}{1 + \Gamma} \cdot \frac{\text{cov}(P_{t+j}, \Delta e_t)}{\text{var}(\Delta e_t)}. \]
Estimation of MRPT

• Define price change:

\[ \Delta \bar{p}_t \equiv \begin{cases} \bar{p}_{L,t} - \bar{p}_{L,t-\tau}, & \text{for LCP,} \\ \bar{p}_{P,t}^* + e_t - \bar{p}_{P,t-\tau}^* - e_{t-\tau}, & \text{for PCP.} \end{cases} \]

• Run regression:

\[ \Delta \bar{p}_t = \alpha + \beta_{MR} \Delta e_t + \epsilon_t \]
Estimation of MRPT

• Define price change:

$$\Delta \bar{p}_t \equiv \begin{cases} 
\bar{p}_{L,t} - \bar{p}_{L,t-\tau} , & \text{for LCP}, \\
\bar{p}^*_{P,t} + e_t - \bar{p}^*_{P,t-\tau} - e_{t-\tau} , & \text{for PCP}.
\end{cases}$$

• Run regression:

$$\Delta \bar{p}_t = \alpha + \beta_{MR} \Delta e_t + \epsilon_t$$

Proposition

$\beta_{MR}$ equals MRPT:

$$\beta_{MR} \equiv \frac{\text{cov}(\Delta \bar{p}_t, \Delta e_t)}{\text{var}(\Delta e_t)} = (1 - \delta \theta) \sum_{\ell=0}^{\infty} (\delta \theta)^\ell \tilde{\Psi}_\ell = \tilde{\Psi}.$$
Numerical Simulation

Twofold purpose of the exercise:

1. Relate currency choice and pass-through to primitives

2. Relax the assumptions of the analytical model
   - Menu Cost price setting
   - Mean reversion in the exchange rate
   - Non-constant $\Gamma$
   - Empirical measures of MRPT
Numerical Simulation

Twofold purpose of the exercise:

1. Relate currency choice and pass-through to primitives

2. Relax the assumptions of the analytical model
   - Menu Cost price setting
   - Mean reversion in the exchange rate
   - Non-constant $\Gamma$
   - Empirical measures of MRPT

- Source of incomplete pass-through:
  - Demand driven variable markups (Kimball demand)
  - Proxy for strategic complementarity (as in Atkeson and Burstein, 2008)
Demand and Costs


\[ q = q(p, P) = \left[1 - \varepsilon(p - P)\right]^{\sigma/\varepsilon}, \quad \sigma > 1, \varepsilon \geq 0 \]

- Markup variability:

\[ \tilde{\Gamma} = -\frac{\partial \mu}{\partial p} = \frac{\varepsilon}{\sigma - 1 + \varepsilon(p - P)} \]
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- Price level dynamics:
  \[ (P_t - \bar{P}) = \alpha (P_{t-1} - \bar{P}) + (1 - \alpha) \bar{\phi} e_t \]
# Calibration

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Value</th>
<th>Source/Moment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Discount Factor</td>
<td>$\delta$</td>
<td>$0.96^{1/12}$</td>
<td>Monthly data</td>
</tr>
<tr>
<td>St.dev. of $e_t$</td>
<td>$\sigma_e$</td>
<td>0.025</td>
<td>Data</td>
</tr>
<tr>
<td>Persistence of $e_t$</td>
<td>$\rho_e$</td>
<td>0.986</td>
<td>Data</td>
</tr>
<tr>
<td>St.dev. of $a_t$</td>
<td>$\sigma_a$</td>
<td>0.08</td>
<td>Abs. Size of Price Adj.</td>
</tr>
<tr>
<td>Persistence of $a_t$</td>
<td>$\rho_a$</td>
<td>0.95</td>
<td>Persistence of new prices</td>
</tr>
<tr>
<td>Inertia in $P_t$</td>
<td>$\alpha$</td>
<td>0.95</td>
<td></td>
</tr>
<tr>
<td>Long-run response of $P_t$</td>
<td>$\bar{\phi}$</td>
<td>0.50</td>
<td></td>
</tr>
<tr>
<td>Cost sensitivity</td>
<td>$\phi$</td>
<td>0.75</td>
<td>Input-Output Tables</td>
</tr>
<tr>
<td>Calvo parameter</td>
<td>$\theta$</td>
<td>0.89</td>
<td>Price Durations</td>
</tr>
<tr>
<td>Menu Cost</td>
<td>$\kappa$</td>
<td>0.05</td>
<td>Price Durations</td>
</tr>
<tr>
<td>Demand elasticity</td>
<td>$\sigma$</td>
<td>5</td>
<td>Steady State Mark-up</td>
</tr>
<tr>
<td>Demand super-elasticity</td>
<td>$\varepsilon$</td>
<td>3</td>
<td></td>
</tr>
</tbody>
</table>
Currency Choice, MRPT and LRPT

Variation in $\Gamma$

Elasticity of Mark-up, $\Gamma = \varepsilon / (\sigma - 1)$

MRPT and LRPT

LRPT

MRPT

LCPPCP
Currency Choice, MRPT and LRPT

Variation in $\phi$

Cost Sensitivity to Exchange Rate, $\phi$

MRPT and LRPT

LCP  PCP
Currency Choice

In the Space of Primitives

Mark-up Elasticity, $\Gamma = \frac{\varepsilon}{\sigma - 1}$

Cost Sensitivity to Exchange Rate, $\phi$

PCP
High Pass-through

LCP
Low Pass-through

Menu Cost

Calvo
Mark-up Elasticity, $\Gamma = \frac{\varepsilon}{\sigma - 1}$

MRPT vs LRPT
Empirical Measures of MRPT

Empirical Measures of MRPT
Cumulative $\Delta e$, Bias-corrected
One-period $\Delta e$, Bias-corrected
Theoretical MRPT
Cumulative $\Delta e$, Biased
Mean Reversion Bias

Mark-up Elasticity, $\Gamma = \epsilon / (\sigma - 1)$
Linking Theory and Evidence

- **MRPT**, approx. pass-through condition on a price change, is a sufficient statistic for currency choice:
  - 25% for LCP versus 95% for PCP

- **MRPT** versus **LRPT**:
  - 25% to over 50% for some LCP items

- Difference in frequency of price adjustment:
  - 10% for LCP versus 7% for PCP

- Models of exogenous currency choice inconsistent with data
  - Backward-looking price setting: LRPT (50% versus 95%)
  - Sorting in the data

- Potential primitives:
  - imported intermediate inputs ($\phi$)
  - variables affecting markup variability ($\Gamma$)
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  - variables affecting markup variability ($\Gamma$)
Frequency and Pass-through

Gopinath and Itskhoki (2009)
Frequency and Pass-through

Theory

- **Long-run Pass-through:**
  \[ \psi = \frac{\phi}{1 + \Gamma} \]

- **Approximation to the profit loss function:**
  \[ I(X) \approx \frac{1}{2} (\sigma - 1) \psi \Sigma \cdot X^2 \geq \kappa, \]
  \[ X \equiv \frac{-a + \phi e}{\sqrt{\Sigma}} \]
  \[ \Sigma \equiv \sigma_a^2 + \phi^2 \sigma_e^2 \]

- **Frequency:**
  \[ \Phi \approx \Pr \left\{ |X| > \sqrt{\frac{2\kappa}{(\sigma - 1)\psi \Sigma}} \right\} \]
Frequency and Pass-through

Simulation

![Graph showing the relationship between frequency and pass-through for All Firms, Importers, and Domestic firms.](image)
Frequency and Pass-through

Simulation

Variation in $\epsilon$
Variation in $\phi$
Variation in $\kappa$

Frequency
Pass-through

0.1 0.15 0.2 0.25 0.3 0.35 0.4
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
# Frequency and Pass-through Simulation

<table>
<thead>
<tr>
<th></th>
<th>Data</th>
<th>Variation in $\epsilon$</th>
<th>Variation in $\kappa$</th>
<th>Variation in $\epsilon$ and $\kappa$</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Slope(Freq., LRPT)</strong></td>
<td>0.56</td>
<td>1.86</td>
<td>0.03</td>
<td>0.55</td>
</tr>
<tr>
<td>Min LRPT</td>
<td>0.06</td>
<td>0.13</td>
<td>0.44</td>
<td>0.22</td>
</tr>
<tr>
<td>Max LRPT</td>
<td>0.72</td>
<td>0.76</td>
<td>0.46</td>
<td>0.57</td>
</tr>
<tr>
<td><strong>Slope(Freq., size)</strong></td>
<td>-0.01</td>
<td>0.23</td>
<td>-0.15</td>
<td>-0.05</td>
</tr>
<tr>
<td>Min size</td>
<td>5.4%</td>
<td>3.8%</td>
<td>4.8%</td>
<td>5.8%</td>
</tr>
<tr>
<td>Max size</td>
<td>7.4%</td>
<td>11.8%</td>
<td>12.2%</td>
<td>8.2%</td>
</tr>
<tr>
<td><strong>Std. dev. of Freq.</strong></td>
<td>0.30</td>
<td>0.11</td>
<td>0.17</td>
<td>0.18</td>
</tr>
<tr>
<td>Min freq.</td>
<td>0.03</td>
<td>0.07</td>
<td>0.06</td>
<td>0.05</td>
</tr>
<tr>
<td>Max freq.</td>
<td>1.00</td>
<td>0.44</td>
<td>0.59</td>
<td>0.61</td>
</tr>
</tbody>
</table>
Figure: ERPT at different horizons by country and currency:

$$\Delta p_{i,t}^c = a_i^c + \sum_{\tau=0}^{T} b_{i,\tau}^c \Delta e_{i,t-\tau} + z_{it}' \delta_i^c + \varepsilon_{it}^c$$
## Pass-through Cond’l on Price Adjustment

**All Goods**

<table>
<thead>
<tr>
<th>Country</th>
<th>Dollar $\beta_D$</th>
<th>s.e.($\beta_D$)</th>
<th>Non-Dollar $\beta_{ND}$</th>
<th>s.e.($\beta_{ND}$)</th>
<th>$\beta_{ND} - \beta_D$</th>
<th>t-stat</th>
<th>$N_g$</th>
<th>$R^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>All Countries</td>
<td>0.24</td>
<td>0.03</td>
<td>0.92</td>
<td>0.04</td>
<td>0.68</td>
<td>13.89</td>
<td>6,637</td>
<td>0.11</td>
</tr>
<tr>
<td>Germany</td>
<td>0.31</td>
<td>0.07</td>
<td>0.87</td>
<td>0.10</td>
<td>0.56</td>
<td>4.71</td>
<td>801</td>
<td>0.22</td>
</tr>
<tr>
<td>Switzerland</td>
<td>0.24</td>
<td>0.11</td>
<td>0.96</td>
<td>0.18</td>
<td>0.72</td>
<td>3.36</td>
<td>130</td>
<td>0.36</td>
</tr>
<tr>
<td>Italy</td>
<td>0.21</td>
<td>0.06</td>
<td>0.84</td>
<td>0.13</td>
<td>0.63</td>
<td>4.31</td>
<td>744</td>
<td>0.18</td>
</tr>
<tr>
<td>Japan</td>
<td>0.23</td>
<td>0.04</td>
<td>0.96</td>
<td>0.06</td>
<td>0.73</td>
<td>10.77</td>
<td>1,733</td>
<td>0.14</td>
</tr>
<tr>
<td>UK</td>
<td>0.19</td>
<td>0.11</td>
<td>0.74</td>
<td>0.17</td>
<td>0.55</td>
<td>2.92</td>
<td>541</td>
<td>0.17</td>
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<tr>
<td>Belgium</td>
<td>0.01</td>
<td>0.07</td>
<td>0.98</td>
<td>0.14</td>
<td>0.98</td>
<td>6.05</td>
<td>97</td>
<td>0.41</td>
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<tr>
<td>France</td>
<td>0.26</td>
<td>0.07</td>
<td>1.03</td>
<td>0.10</td>
<td>0.77</td>
<td>6.11</td>
<td>425</td>
<td>0.21</td>
</tr>
<tr>
<td>Sweden</td>
<td>0.28</td>
<td>0.14</td>
<td>0.94</td>
<td>0.21</td>
<td>0.66</td>
<td>2.73</td>
<td>160</td>
<td>0.25</td>
</tr>
<tr>
<td>Spain</td>
<td>0.46</td>
<td>0.14</td>
<td>0.83</td>
<td>0.27</td>
<td>0.37</td>
<td>1.19</td>
<td>164</td>
<td>0.20</td>
</tr>
<tr>
<td>Netherlands</td>
<td>0.21</td>
<td>0.09</td>
<td>0.89</td>
<td>0.35</td>
<td>0.67</td>
<td>1.85</td>
<td>126</td>
<td>0.08</td>
</tr>
<tr>
<td>Canada</td>
<td>0.22</td>
<td>0.13</td>
<td>0.66</td>
<td>0.45</td>
<td>0.44</td>
<td>1.00</td>
<td>1,654</td>
<td>0.03</td>
</tr>
</tbody>
</table>

$$\Delta \bar{p}_{i,t} = \left[ \beta_D \cdot D_i + \beta_{ND} \cdot (1 - D_i) \right] \cdot \Delta c e_{i,t} + Z'_{i,t} \gamma + \epsilon_{i,t}$$