Asymmetries and Non-Linearities in Exchange Rate Pass-through

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The views expressed here should not be interpreted as reflecting the views of the Bureau of Labor Statistics, the Federal Reserve Board of Governors, or any other person associated with the Federal Reserve System.
Motivation

- Exchange rates often go through periods of appreciations and depreciations.

**CAD/USD**

Source: Board of Governors of the Federal Reserve System (US)
fred.stlouisfed.org
Motivation

- Exchange rates often go through periods of appreciations and depreciations.

  CAD/USD

- However, the standard assumption is that exchange rate appreciations and depreciations pass through symmetrically to import prices.
Aggregate pass-through for foreign currency depreciations (-) and appreciations (+) into non-fuel, non-tech products:

95% confidence bands plotted for difference.
Questions

- Is pass-through of exchange rates into import prices asymmetric? Is it non-linear?
- If these asymmetries or non-linearities exist, do they tell us something about market structure or the nature of demand?
We show that this pass-through is asymmetric: foreign appreciations tend to pass through faster.
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This result is unlikely to stem from a selection effect causing product exit, but price stickiness may be important in some cases.

The importance of this asymmetry varies by sector, suggesting that the nature of competition and price setting plays a role.

We find no statistically significant non-linearities.

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Preview of results

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  - This result is unlikely to stem from a selection effect causing product exit, but price stickiness may be important in some cases.
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Existing literature

- The standard pass-through regression (everything in logs):

\[ \Delta p_t = \alpha + \beta \Delta e_t + \delta \Delta c_t + \epsilon_t \]

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- What has been established in the literature?
  - Pass-through of exchange rates into U.S. import prices is incomplete and fairly low.
  - Aggregate long-run pass-through elasticity around 0.4 (Campa and Goldberg 2005); product-level elasticity is similar (Gopinath and Itskhoki, 2010).
  - Pass-through is low even conditional on a price change. (Gopinath and Itskhoki, 2010)
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  - Pass-through is low even conditional on a price change. (Gopinath and Itshoki, 2010)
- Pass-through has been declining secularly since the 70s. (Marazzi, 2005)
Data

- We use monthly product-level prices from the BLS International Price Program (IPP) for years 1994-2014.
- Other data: foreign CPI, exchange rates (IFS), commodity prices (IMF)
BLS data

- Probability proportionate to size sampling at the reporter/item level
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- Reported prices
  - Raw data includes list prices, transaction prices, estimated prices, including intrafirm prices.
- Net prices
  - Reflect dollar-denominated transaction prices, by making any necessary adjustments to reported prices.
  - Missing prices are estimated using various methods.
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Asymmetries in pass-through

We augment a standard pass-through regression to separately respond to bilateral exchange rate appreciations and depreciations.
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$$\Delta p_{i,j,t} = \sum_{k=0}^{18} \{ \beta_k^+ \Delta e_{j,t-k}^+ + \beta_k^- \Delta e_{j,t-k}^- \} + [\ldots] + \epsilon_{i,j,t}$$

$$\Delta e_{j,t}^+ \begin{cases} \Delta e & \Delta e > 0 \\ 0 & \Delta e \leq 0 \end{cases}$$

$$\Delta e_{j,t}^- \begin{cases} \Delta e & \Delta e < 0 \\ 0 & \Delta e \geq 0 \end{cases}$$

Country x stratum dummies, monthly time dummies, foreign CPI are controls.
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- The impulse response of a price at horizon $h$ after an exchange rate shock is simply $\sum_{k=0}^{h} \beta_k^+$ or $\sum_{k=0}^{h} \beta_k^-$
Asymmetry results

Across all goods, pass-through for foreign appreciations (+) is faster than for foreign depreciations (−), but the pass-through at 18 months is the same:

95% confidence bands plotted for difference.
Across sectors for goods that Rauch (1999) identifies as differentiated goods, asymmetries are more pronounced:

95% confidence bands plotted for difference.
Issue 1: Nominal rigidities

- Differences in the speed of pass-through suggest that they may be caused by differences in price adjustment.
- If foreign appreciations cause foreign firms to adjust prices faster, the pass-through would be faster.
Controlling for price stickiness: MRPT

- Following Gopinath, et al. (2010), we can eliminate the effect of nominal price rigidities on pass-through estimates by focusing on what they call medium-run pass-through (MRPT), where subscript $c$ denotes the cumulative change between time $t$ and the last price change $t - k$ for good $i$ from country $j$:

$$
\Delta p_{i,j,c} = \beta^+ \Delta e_{j,c}^+ + \beta^- \Delta e_{j,c}^- + \Delta Z_c + \epsilon_{i,t}
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Unfortunately, this makes time dummies less natural, and so we include other explanatory variables $\Delta Z$ like the U.S. CPI and a measure of global non-oil commodity prices. Country/strata fixed effects are still included.
Table 1: Pass-through conditional on a price change

<table>
<thead>
<tr>
<th></th>
<th>Depreciation</th>
<th>Appreciation</th>
<th>Difference</th>
<th>N</th>
<th>$R^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>All goods</td>
<td>0.210***</td>
<td>0.178***</td>
<td>-0.032</td>
<td>138,877</td>
<td>0.08</td>
</tr>
<tr>
<td>Differentiated (strict)</td>
<td>0.154***</td>
<td>0.267***</td>
<td>0.113**</td>
<td>41,632</td>
<td>0.12</td>
</tr>
<tr>
<td>Differentiated (loose)</td>
<td>0.175***</td>
<td>0.214***</td>
<td>0.039</td>
<td>62,545</td>
<td>0.12</td>
</tr>
<tr>
<td>By end-use:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0. Foods, feeds, bev.</td>
<td>0.130***</td>
<td>0.065*</td>
<td>-0.065</td>
<td>24,026</td>
<td>0.03</td>
</tr>
<tr>
<td>1. Industrial supplies</td>
<td>0.320***</td>
<td>0.134**</td>
<td>-0.186</td>
<td>47,994</td>
<td>0.08</td>
</tr>
<tr>
<td>2. Capital goods ex auto</td>
<td>0.249***</td>
<td>0.145**</td>
<td>-0.104</td>
<td>13,200</td>
<td>0.19</td>
</tr>
<tr>
<td>3. Automotive products</td>
<td>0.133</td>
<td>0.369***</td>
<td>0.237**</td>
<td>1,157</td>
<td>0.22</td>
</tr>
<tr>
<td>4. Consumer goods</td>
<td>0.113***</td>
<td>0.225***</td>
<td>0.112</td>
<td>13,172</td>
<td>0.16</td>
</tr>
</tbody>
</table>

Note: *** denotes significance at the 99% level, ** at the 95% level, and * at the 90% level, with standard errors clustered at the sector (strata) level.

- Conditioning on a price change, some evidence that pass-through is still asymmetric, but only for differentiated goods.
Issue 2: Selection

- Foreign appreciations might also induce products to exit the market, as the desired dollar price rises and the foreign firm stops selling it rather than letting the price increase through.
- This would bias the foreign appreciation pass-through towards zero, potentially understating the true asymmetry of pass-through.
We look for evidence of this selection effect by estimating a linear probability model of exit:

\[
\text{prob}(\text{exit}_{i,j,t}) = \sum_{k=0}^{18} \{ \beta^+_k \Delta e^+_{j,t-k} + \beta^-_k \Delta e^-_{j,t-k} \} + [...] + \epsilon_{i,j,t}
\]
Searching for Selection

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We take into account the reason for item exit as listed in the BLS survey.
Selection results: Selected exits

95% confidence bands plotted for difference.

- Focusing on exits likely to be endogenous, there is no evidence of selection driving the asymmetric pass-through results.
Non-linearities in pass-through

- Many theories of asymmetric pass-through also imply non-linear pass through: larger shocks may have higher pass-through than smaller shocks.

\[ \Delta p_{i,j,t} = h \sum_{k=0}^{\infty} \left\{ \beta_k + k (\Delta e_{j,t} - k) - k \gamma_k + k \delta_k \right\} + \alpha_t + \sigma_t + \epsilon_{i,j,t} \]
Non-linearities in pass-through

- Many theories of asymmetric pass-through also imply non-linear pass through: larger shocks may have higher pass-through than smaller shocks.
- Adding square and cube terms to our augmented pass-through regression allows for differential pass-through depending on the size of the shock.

\[
\Delta p_{i,j,t} = \sum_{k=0}^{h} \{ \beta_k^+ (\Delta e^+)^{j,t-k} + \gamma_k^+ (\Delta e^+)^{2,j,t-k} + \delta_k^+ (\Delta e^+)^{3,j,t-k} \} \\
+ \sum_{k=0}^{h} \{ \beta_k^- (\Delta e^-)^{j,t-k} + \gamma_k^- (\Delta e^-)^{2,j,t-k} + \delta_k^- (\Delta e^-)^{3,j,t-k} \} \\
+ \delta P_{j,t} + \alpha_t + s_t + \epsilon_{i,j,t}
\]
Non-linearity results

Non-linearity in pass-through (foreign appreciations)

95% confidence bands plotted for difference.

- Large exchange rate changes pass through a bit slower than smaller ones, but any difference is small.
At the sectoral level, product entry/exit (selection) can cause asymmetries (Nakamura and Steinsson 2012).

Product-level sources of asymmetric pass-through (Ritz 2015):

- Demand: habit formation, demand curves with non-constant curvature
- Supply: non-constant marginal costs, capacity constraints

Many models used in macro and trade imply symmetric or near-symmetric pass-through.
We proposed a simple partial-equilibrium model of sticky prices and convex costs to raising output.
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Firms face monopolistic competition, idiosyncratic productivity shocks $a$, and aggregate real exchange rate shocks $e$. With menu cost $\kappa$, they are allowed to change their price, maximizing their discounted value.

$$V(p, a, e) = \max \{ V^A(p, a, e), V^N(p, a, e) \},$$

$V^A$ is the value of the firm if it adjusts its price:

$$V^A(p, a, e) = \max_{p'} \Pi(p', a, e) - \kappa + \beta E[V(p', a', e')],$$

$V^N$ is the value of the firm if it does not adjust its price:

$$V^N(p, a, e) = \Pi(p, a, e) + \beta E[V(p, a', e')].$$

$\Pi(p, a, e)$ is the flow profit of the firm.
Flow profit has two key elements:

\[
\Pi(p', a, e) = \frac{p'q(p')}{e} - \frac{\bar{c}}{a}q(p') - \mathbb{I}[q(p') > q(p)]\phi \bar{c}(q(p') - q(p))^2
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1. \(q(p)\) is a Klenow-Willis (2006) demand curve, inducing firms to want to price closer to the sectoral price \(\bar{P}\), generating incomplete pass-through, even in the long run:

\[ q(p) = \left(1 - \epsilon \ln \frac{p}{\bar{P}}\right)^{\frac{\theta}{\epsilon}}. \]

This generates an effective demand elasticity:

\[ \tilde{\theta} = \frac{\theta}{1 - \epsilon \ln\left(\frac{p}{\bar{P}}\right)}. \]
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2. Convex adjustment costs \( \phi \) if increasing quantity produced \( (q(p') > q(p)) \).
Parameterization

Table 2: External Parameterization

<table>
<thead>
<tr>
<th>Value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \theta )</td>
<td>4 Elasticity of substitution</td>
</tr>
<tr>
<td>( \beta )</td>
<td>0.94(^{1/2} ) Discount factor</td>
</tr>
<tr>
<td>( \rho_a )</td>
<td>0.96 AR(1) coefficient for productivity</td>
</tr>
<tr>
<td>( \rho_e )</td>
<td>0.99 AR(1) coefficient for exchange rates</td>
</tr>
<tr>
<td>( \sigma_e )</td>
<td>0.025 Standard deviation for exchange rates</td>
</tr>
</tbody>
</table>

Table 3: Parameterization via Indirect Inference

<table>
<thead>
<tr>
<th>Value</th>
<th>Description</th>
<th>Targeted Moment</th>
<th>Target</th>
<th>Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \epsilon )</td>
<td>3.63 Super-elasticity</td>
<td>Long-run PT</td>
<td>0.4</td>
<td>0.43</td>
</tr>
<tr>
<td>( \kappa )</td>
<td>0.025 Menu Cost</td>
<td>Frequency of ( \Delta p )</td>
<td>0.09</td>
<td>0.076</td>
</tr>
<tr>
<td>( \phi )</td>
<td>2.80 Convex adj. cost</td>
<td>PT asym. (max)</td>
<td>0.10</td>
<td>0.087</td>
</tr>
<tr>
<td>( \sigma_a )</td>
<td>0.047 std(productivity)</td>
<td>Median</td>
<td>0.08</td>
<td>0.026</td>
</tr>
</tbody>
</table>
Numerical exercise to see if these mechanisms can generate similar pass-through patterns:
Preliminary results

![Pass-through (model)](image1)

- **Pass-through (model)**
  - Positive (foreign appreciation)
  - Negative (foreign depreciation)

![Difference (model)](image2)

- **Difference (model)**

![Pass-through](image3)

- **Pass-through**
  - Positive (foreign appreciation)
  - Negative (foreign depreciation)

![Difference](image4)

- **Difference**
Conclusion

- Foreign appreciations pass through faster than depreciations.
- Asymmetries are still present conditional on a price change.
- Selection does not appear to be strongly asymmetric.
- Non-linearities are negligible.
- A theory of sticky prices with strategic complementarities and capacity constraints is generally capable of matching these facts.
Existing literature on asymmetries and non-linearities

- Pollard and Coughlin (2004)
  - Industry-level study
  - Existence and size of asymmetry varies across industries.
  - Large movements in exchange rates are associated with higher pass-through.

- Bussiere (2013)
  - Aggregate-level study of G7 countries, including the U.S.
  - Non-linearities vary from country to country.
  - Evidence is stronger for asymmetries than for non-linearities.
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Existing literature on asymmetries and non-linearities

Razafindrabe (2017) uses French firm-level data to show that depreciation pass through faster than appreciation, largely due to price stickiness.
Existing literature on asymmetries and non-linearities

- Razafindrabe (2017)
  - French firm-level data
  - Depreciations pass through faster than appreciations
  - Largely the result of price stickiness
Price changes

95% confidence bands plotted for difference.