What Can Stockouts Tell Us About Inflation? 
Evidence from Online Micro Data

Alberto Cavallo 
Harvard Business School

Oleksiy Kryvtsov 
Bank of Canada

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The views expressed here are ours, and they do not necessarily reflect the views of the Bank of Canada
Motivation

- Inflation during Covid: small initial decline, quickly rebounded, reached decades high by end 2021

- Did supply disruptions play an important role in these price dynamics?
Paper summary

- Create two high-frequency measures of consumer product shortages in 7 countries
  - temporary stockouts, discontinued products

- Document a multi-fold rise in shortages in nearly all sectors early in the pandemic
  - Over time, the composition of shortages evolved from many temporary stockouts to mostly discontinued products, concentrated in fewer sectors

- Are shortages associated with inflation?

- Are the inflation effects stronger for imported goods?

- What do observed prices and shortages imply about the cost to replenish inventories?
Prices and stockouts micro data

- We use daily product data collected by PriceStats (The Billion Prices Project)
- Data scraped from websites of large multi-channel retailers that sell mostly offline

<html>
  <product> Leche Condensada </product>
  <brand> Nestlé </brand>
  <td price> $1.199 Uni </td>
</html>

<table>
<thead>
<tr>
<th>ID</th>
<th>ID2</th>
<th>PRODUCT</th>
<th>BRAND</th>
<th>SIZE</th>
<th>BULK PRICE</th>
<th>PRICE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3429</td>
<td>Leche Condensada</td>
<td>Leche</td>
<td>Lata 395 grs.</td>
<td>xKilo: $1.744</td>
<td>6.39</td>
</tr>
<tr>
<td>2</td>
<td>3422</td>
<td>Leche Condensada</td>
<td>Nestlé</td>
<td>Desechable, Lata 395 grs.</td>
<td>xKilo: $2.023</td>
<td>7.99</td>
</tr>
<tr>
<td>3</td>
<td>995</td>
<td>Leche Condensada</td>
<td>Nestlé</td>
<td>Envasa Flexible 350 grs.</td>
<td>xKilo: $2.5</td>
<td>8.99</td>
</tr>
<tr>
<td>4</td>
<td>8104</td>
<td>Leche Condensada</td>
<td>Nestlé</td>
<td>Lata 897 grs.</td>
<td>xKilo: $1.763</td>
<td>6.99</td>
</tr>
<tr>
<td>5</td>
<td>1567</td>
<td>Leche Condensada</td>
<td>Nestlé</td>
<td>Pack 2 unidades, Lata 200 grs. c/u</td>
<td>xKilo: $1.998</td>
<td>1.199</td>
</tr>
</tbody>
</table>
Measuring shortages in retail (sector $j$, country $c$, date $t$)

Temporary Stockouts ($TOOS_{jc,t}$) = \frac{\# \text{ out of stock}_{jc,t}}{\# \text{ total products}_{jc,t}}

Figure 1: Identifying Stockouts on a Retailer’s Website
Measuring shortages in retail (sector $j$, country $c$, date $t$)

- **Temporary Stockouts** ($TOOS_{jc,t}$) = \[
\frac{\# \text{out of stock}_{jc,t}}{\# \text{total products}_{jc,t}}
\]

- **Permanent Stockouts** ($POOS_{jc,t}$) = \[
1 - \frac{\# \text{total products}_{jc,t}}{\# \text{total products}_{jc, Jan-2020}}
\]

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- **Temporary Stockouts** ($TOOS_{jc,t}$) = \( \frac{\text{# out of stock}_{jc,t}}{\text{# total products}_{jc,t}} \)

- **Permanent Stockouts** ($POOS_{jc,t}$) = \( 1 - \frac{\text{# total products}_{jc,t}}{\text{# total products}_{jc,Jan-2020}} \)

- **All Stockouts** = \( 1 - \frac{\text{# total products}_{jc,t} - \text{# out of stock}_{jc,t}}{\text{# total products}_{jc,Jan-2020}} \)
Micro data in this paper

- We focus on 70 retailers in 7 countries that show “out of stock” information

<table>
<thead>
<tr>
<th></th>
<th>Products</th>
<th>Retailers</th>
<th>Coverage of All CPI Weights, (%)</th>
<th>Coverage of Goods CPI Weights, (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Canada</td>
<td>194,151</td>
<td>11</td>
<td>27</td>
<td>80</td>
</tr>
<tr>
<td>China</td>
<td>49,685</td>
<td>3</td>
<td>38</td>
<td>76</td>
</tr>
<tr>
<td>France</td>
<td>372,962</td>
<td>11</td>
<td>32</td>
<td>63</td>
</tr>
<tr>
<td>Germany</td>
<td>297,320</td>
<td>13</td>
<td>27</td>
<td>52</td>
</tr>
<tr>
<td>Japan</td>
<td>95,313</td>
<td>7</td>
<td>30</td>
<td>68</td>
</tr>
<tr>
<td>Spain</td>
<td>171,400</td>
<td>8</td>
<td>31</td>
<td>56</td>
</tr>
<tr>
<td>USA</td>
<td>777,554</td>
<td>17</td>
<td>21</td>
<td>62</td>
</tr>
<tr>
<td>All</td>
<td>1,958,385</td>
<td>70</td>
<td>29</td>
<td>65</td>
</tr>
</tbody>
</table>

- **Sectors**: Food & Beverages, Furnishings & Household, Health, Electronics, Other goods
  - **Not included**: Cars, Gasoline, Alcohol & Tobacco, Apparel
- We start at the disaggregated COICOP 3-digit level, then build aggregate series using official CPI weights
Stockout dynamics in the United States

(a) All Stockouts

(b) Temporary and Permanent Stockouts
Stockout dynamics in 7 countries
Stockout dynamics in 7 countries

(a) Temporary Stockouts

(b) Permanent Stockouts
In the United States, stockouts are more persistent in Food & Beverages
Are product shortages associated with inflation?

(a) Official CPIs

(b) Online Price Indices
Estimation of responses to stockouts shocks, 235 sectors in 7 countries

- Estimate the response of inflation to an exogenous stockout disturbance at the 3-digit level

- **Stockout shock:** residual of an AR(1) process for the weekly stockout rate in sector \( j \) country \( c \)

\[
OOS_{cj,t} = c_{cj} + \beta_{cj} OOS_{cj,t-1} + \epsilon_{cj,t}
\]

- Estimate impulse responses to the stockout shock using linear projections (Jordà, 2005):

\[
X_{cj,t+h} - X_{cj,t-1} = c^{(h)} + \sum_{l=0}^{L} \beta_{l}^{(h)} \epsilon_{cj,t-l} + \sum_{n=1}^{N} \delta_{n}^{(h)} X_{cj,t-n} + D_{cj} + error_{cj,t}^{(h)}
\]

- \( X_{cj,t} \) is **monthly inflation rate** or stockout rate (TOOS or POOS)
- \( D_{cj} \) are sector-country fixed effects
- \( \hat{\beta}_{l}^{(h)} \) provide the **estimated impulse response** at horizon \( h \)
Result 1: Shortages are associated with rising sector prices within 2 months

Figure 7: Responses to a Stockout Shock in a 3-digit sector in 7 countries

- Doubling stockouts from 10% to 20% increases sector inflation by 1.6 ppt (annualized rate)
Result 2a: Inflation response is larger & longer in import intensive sectors

- Split 235 sectors (7 countries) into groups below/above weighted median import share (0.24)
  - Low shares: unprocessed food, plants, printed material
  - High shares: video/audio equipment, furniture, jewelry and watches
Micro evidence from a large U.S. retailer

- Country-of-origin information for each good provided by the retailer (from Cavallo, Gopinath, Neiman, Tang (2021))
- Imported goods had more frequent stockouts, longer stockouts, more inflation

<table>
<thead>
<tr>
<th></th>
<th>U.S. Retailer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of products</td>
<td>16,953</td>
</tr>
<tr>
<td>imported</td>
<td>12,275</td>
</tr>
<tr>
<td>domestic</td>
<td>4,678</td>
</tr>
<tr>
<td>Fraction of stockouts, %</td>
<td>5.3</td>
</tr>
<tr>
<td>imported</td>
<td>5.2</td>
</tr>
<tr>
<td>domestic</td>
<td>4.0</td>
</tr>
<tr>
<td>Stockout duration, days</td>
<td>27.4</td>
</tr>
<tr>
<td>imported</td>
<td>26.0</td>
</tr>
<tr>
<td>domestic</td>
<td>18.5</td>
</tr>
<tr>
<td>Product inflation, ann %</td>
<td>2.8</td>
</tr>
<tr>
<td>imported</td>
<td>3.3</td>
</tr>
<tr>
<td>domestic</td>
<td>2.3</td>
</tr>
</tbody>
</table>

Table 2: Summary statistics for a large U.S. retailer.
Result 2b: After temp stockouts prices tend to rise

Price-relative = cum log p-change \( t \) days before/after day -1 relative to cum log price change for all goods in L3 sector
Result 2b: After temp stockouts prices tend to rise, especially for imported goods

Price-relative = cum log p-change t days before/after day -1 relative to cum log price change for all goods in sector
What can stockouts tell us about the cost of replenishing inventories?

• Our stockouts matched surveys of “supply disruptions” closely until May 2021, but have diverged since
• Firms can adjust to changes in the replacement cost via stockouts and prices \(\rightarrow\) we cannot infer the cost only from stockout dynamics
• We use a model to endogenize inventory decisions, and estimate cost based on observable OOS and prices
What can stockouts and prices tell us about the cost to replenish inventories?

- Model of monopolistic firm with inventories (builds on Kryvtsov and Midrigan, 2013)
  - Inventories help firm to manage incidence of stockouts \( \rightarrow \) tradeoff: inventory-holding cost vs unable to meet demand
  - Convex cost of adjusting inventories \( \rightarrow \) higher stockouts increase replacement costs
  - Allows for both changes in demand and supply to increase the inventory replacement cost

- FOC: probability of temporary stockout depends on firm’s price and current/future replacement cost

\[
\psi'(v_{jt}(i)) = \frac{\Omega_{jt}(i) - (1 - \delta_j)E_t [Q_{t,t+1}\Omega_{jt+1}(i)]}{P_{jt}(i) - (1 - \delta_j)E_t [Q_{t,t+1}\Omega_{jt+1}(i)]},
\]

\( \rightarrow \) We can use the observed OOS and prices to estimate the cost to replenish inventories over time

- Conditional on cost, prices and stockouts are negatively correlated \( \rightarrow \) so co-movement of prices and stockouts suggests higher costs
Estimated Replacement Cost – Temporary Stockouts

- Electronics $\rightarrow$ cost dynamics similar to OOS because prices are relatively stable
- Food and Beverages $\rightarrow$ cost dynamics change significantly when we account for prices
Estimated Replacement Cost – All Stockouts

- Replacement cost increases more if we include permanent stockouts, particularly for Food and Beverages.
Result 3: Inflationary impact is stronger, twice as high for imported goods

- With endogenous stockouts
  - Inflation responses are stronger but less persistent
  - Inflation impact twice as high for imported goods

Figure 11: Responses to Real Replacement Cost Shocks in 3-Digit Sectors, in 7 Countries
Key results and takeaways

- Widespread increase in shortages during the pandemic

- The composition and visibility of shortages changes over time \( \rightarrow \) from temporary stockouts affecting nearly all categories to permanently discontinued goods concentrated in fewer sectors

- Shortages have economically significant inflationary effects, within 1 to 3 months

- Effects are larger and more persistent for imported goods and import-intensive sectors

- Co-movement of stockouts and prices suggest higher cost of replenishing inventories was an important driver of inflation in this period
  - Increasing again in Q1 2022