Estimation of Aggregate Demand and Supply Shocks Using Commodity Transaction Data

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Note: CPI is calculated by the tax-included price.
Source: Consumer Price Index, Ministry of Internal Affairs and Communications.
Central Question

• Japanese economy has experienced ups and down in inflation rate. Demand shock or supply shock, which is the main cause of the change?

• What is the reaction of aggregate demand and supply to large macroeconomic shock such as The Global Financial Crisis, The Great East Japan Disaster, the change in consumption tax, and Abenomics?
Motivation

• Rapid integration between Macroeconomics and Microeconomics

Most people use micro data to estimate structural parameters of macroeconomic model (Consumption, Investment, Unemployment, Productivity, Price Change Frequency).

However, clear dichotomy between Macro and Micro remains in estimating aggregate demand and supply.
The identification of demand and supply curves has been one of the central issues in history of econometrics.

- Working Brothers (Elmer, Holbrook) (1925, 27) classic!

- **Microeconomics Approach:**
  - Berry et al. (1995) instrumental variable approaches
  - Byrne et al. (2015) structural approach (no iv)

- **Macroeconomic Approach:**
  - Blanchard and Quah (1989): long run restriction
  - Potential GDP (Supply) and GDP Gap (Demand)
This Paper

• Based on microdata, we estimate macroeconomic aggregate demand and supply shocks for about 9 years in Japanese economy
• Three Steps
  1) estimate demand and supply curves
  2) Estimate demand and supply shocks
  3) aggregate the shocks over commodities and categories
• Good Point: timely estimate, weak theory requirements
• Bad Point: service, durable, fresh foods not included
Intuition

• From Point of Sales data, we can observe movements of transaction prices and quantities.

• If we know the shape of demand and supply curves, we can decompose the movements of equilibrium prices and quantities into the changes in demand curves and supply curves.
Given demand and supply curves, we can uniquely decompose the movements of price and quantity into (1) demand and (2) supply shock.
The representative consumer has the following separable utility function at time $t$:

$$U_t = U(C^1_t, C^2_t, ..., C^J_t),$$

$$C^j_t = \left( \sum_{i \in \Theta^j_t} a^i_t x^i_t \frac{\sigma_j}{\sigma_j - 1} \right)^{\frac{\sigma_j}{\sigma_j - 1}}, \quad a^i_t \geq 0, \quad \sigma_j > 0$$

$x^i_t$: consumption of commodity $i$ at time $t$.

$\Theta^j_t$: the commodity space of category $j$ at time $t$.

$C^j_t$: the aggregate consumption of category $j$ at time $t$.

$a^i_t$: the time varying weights for consumption of category $j$ and for commodity $i$ at time $t$. 
The optimal consumption for commodity \( i \), given the category aggregate, is given by the following simple compensated demand function:

\[
\chi_t^i = C_t^j \left( \sum_{k \in \Theta_t^j} a_t^k \sigma_j p_t^{k(1-\sigma_j)} \right)^{\frac{\sigma_j}{1-\sigma_j}} a_t^{\sigma_j} p_t^{i(1-\sigma_j)}.
\]

Denoting,

\[
P_t^j = \left( \sum_{k \in \Theta_t^j} a_t^k \sigma_j p_t^{k(1-\sigma_j)} \right)^{\frac{1}{1-\sigma_j}}
\]

and taking logged time differences, we obtain:

\[
\Delta \ln(\chi_t^i) = \Delta \ln(C_t^j) - \sigma_j \Delta \ln(p_t^i) + \sigma_j \Delta \ln(P_t^j) + \epsilon_t^i \tag{1}
\]
\[ \Delta \ln(x_t^i) = \Delta \ln(C_t^j) - \sigma_j \Delta \ln(p_t^i) + \sigma_j \Delta \ln(P_t^j) + \epsilon_t^i, \text{ where } \epsilon_t^i = \sigma_j \Delta \ln(a_t^i). \]

Feenstra (1994) took the difference from the reference country to control for commodity specific (macroeconomic) component.

**BUT**

(1) Large level of commodity turnover occurs.

(2) The observation of the reference good itself will be dropped, which is a large loss of the observation.
We use the following double differences:

\[
\Delta \ln(x_t^i) - \frac{1}{\#(\Theta_t^{j,b}) - 1} \sum_{k \in \Theta_t^{j,b}, k \neq i} \Delta \ln(x_t^k)
\]

\[
= -\sigma_j \left( \Delta \ln(p_t^i) - \frac{1}{\#(\Theta_t^{j,b}) - 1} \sum_{k \in \Theta_t^{j,b}, k \neq i} \Delta \ln(p_t^k) \right) + \tilde{\varepsilon}_t^i
\]

\[
\tilde{\varepsilon}_t^i = \sigma_j \Delta \ln(a_t^i) - \frac{1}{\#(\Theta_t^{j,b}) - 1} \sum_{k \in \Theta_t^{j,b}, k \neq i} \sigma_j \Delta \ln(a_t^k),
\]

where \(\#(\Theta_t^{j,b})\) is the number of products included in the product set for the barcode \(b, \Theta_t^{j,b}\).
For simplification, denote

\[
\tilde{x}_t^i = \Delta \ln(x_t^i) - \frac{1}{\#(\Theta_t^{j,b})} \sum_{k \in \Theta_t^{j,b}, k \neq i} \Delta \ln(x_t^k),
\]

\[
\tilde{p}_t^i = \Delta \ln(p_t^i) - \frac{1}{\#(\Theta_t^{j,b})} \sum_{k \in \Theta_t^{j,b}, k \neq i} \Delta \ln(p_t^k).
\]

Then, the demand equation becomes,

\[
\tilde{x}_t^i = -\sigma_j \tilde{p}_t^i + \tilde{\varepsilon}_t^i. \tag{2}
\]

Following Feenstra (1994) and Broda and Weinstein (2010),
we assume the following simple supply function,

\[
\Delta \ln(x_t^i) = \omega_j \Delta \ln(p_t^i) + S_t^j + \delta_t^i \tag{3}
\]

\(\omega_j\) : constant parameter

\(\delta_t^i\) : supply shock that shifts the supply curve

\(S_t^j\) : category specific component (macroeconomic shock)
Taking additional differences within the same barcode, as for the demand curve, we obtain:

\[
\Delta \ln(x_t^i) = \omega_j \left( \Delta \ln(p_t^i) - \frac{1}{\#(\Theta_t^{j,b}) - 1} \sum_{k \in \Theta_t^{j,b}, k \neq i} \Delta \ln(p_t^k) \right) + \tilde{\delta}_t^i
\]

\[
\tilde{\delta}_t^i = \delta_t^i - \frac{1}{\#(\Theta_t^{j,b}) - 1} \sum_{k \in \Theta_t^{j,b}, k \neq i} \delta_t^k
\]

Using the same notation as in (2), we obtain the following supply curve:

\[
\hat{x}_t^i = \omega_j \tilde{p}_t^i + \tilde{\delta}_t^i \quad (4)
\]
Identification

• Our main identification assumption for estimating the elasticities, $\sigma_j$ and $\omega_j$, is the orthogonality between the shocks for supply and demand, $\tilde{\delta}_t^i$ and $\tilde{\varepsilon}_t^i$.

• We use the following three moment conditions.

$$E[\tilde{\delta}_t^i \tilde{\varepsilon}_t^i] = 0$$

$$E \left[ \tilde{\delta}_t^i \tilde{\varepsilon}_t^i \right] = 0$$

$$E \left[ \tilde{\delta}_t^i \tilde{\varepsilon}_t^i \right] = 0$$
• we treat the estimate
  with **negative** slope as the elasticity for **demand** curve,
  while the one with **positive** slope as for the **supply** curve.

• If the estimated pair of the elasticities shows that both
curves have the **same** sign, we **drop** such category.

• After obtaining the estimates of the elasticities, \((\hat{\sigma}, \hat{\omega})\), we plug them
into (1) and (3), which gives us the following two sets of shocks:

\[
\hat{\epsilon}_t^i \equiv \Delta \log(x_t^i) + \hat{\sigma} \Delta \log(p_t^i)
\]

\[
\hat{\delta}_t^i \equiv \Delta \log(x_t^i) - \hat{\omega} \Delta \log(p_t^i)
\]
\[ \hat{\varepsilon}_t^i \equiv \Delta \ln(x_t^i) + \hat{\sigma}\Delta \ln(p_t^i) \]

\[ \hat{\delta}_t^i \equiv \Delta \ln(x_t^i) - \hat{\omega}\Delta \ln(p_t^i) \]

• \( \hat{\varepsilon}_t^i \) and \( \hat{\delta}_t^i \) contain both commodity- and category-specific shocks that shift the category-level demand and supply curves, respectively.

• Then, we take the average of these shocks with Törnqvist weights of sales.

※ To take the first differences in price and quantity, for each product, we need price and quantity information at two different periods, current and base periods.

New goods that exist at current period but did not exist at the base period have to be dropped!
Figure 2: New Product Ratio (Sales Weights)

Foods

Daily Commodities

- GMS
- SMT
- DRG
- CVS
The Role of Product Turnover

• Product Turnover is not constant, high in 2008 and 2014.
• If firms use product turnover as a means of price adjustment, and if product turnover is not iid, ignoring new goods might create biases in estimating price index, thus, demand and supply shocks.
Two Elasticities

• Continuing Goods *(Barcode Level)*
  Observations: Price of Commodity at each store
  Restriction: Goods that have sales records in base (one year before) and the current periods

• All goods *(Producer Level)*
  Observations: Unit value price of each store
  Including new goods that have no sales record in base period.
Data

• Japanese store–level scanner data, known as the SRI by INTAGE Co,. Ltd.
• The sample period: from January 2007 to February 2016.
• The data set covers about 3,000 stores, located all over Japan, that can be classified into four different types:
  general merchandise stores (GMS)
  supermarkets (SMT)
  drug stores (DRG), and convenience stores (CVS)
• We limit the sample to those with volume information → 1,057 categories are available.
We use category 2 level product classifications.

<table>
<thead>
<tr>
<th>Category 1</th>
<th>Category 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Laundry detergent</td>
<td>Powder / Highly concentrated</td>
</tr>
<tr>
<td></td>
<td>Powder / concentrated</td>
</tr>
<tr>
<td></td>
<td>Powder / Non-concentrated</td>
</tr>
<tr>
<td></td>
<td>Liquid / Highly concentrated</td>
</tr>
<tr>
<td></td>
<td>Liquid / concentrated</td>
</tr>
<tr>
<td></td>
<td>Liquid/ Non-concentrated</td>
</tr>
<tr>
<td></td>
<td>Others</td>
</tr>
</tbody>
</table>
Summary of Monthly Transaction Data (1)

(1) Volume of Sales (Continuing vs. New Goods)

(2) Volume of Sales (Food vs. Daily Commodities)

(3) New Product Ratio (Food vs. Daily Commodities)

Note: Monthly point of sale data for GMS, STM, DRG, and CVS from January 2007 to February, 2016. Tobacco is not included.
Note: Monthly point of sale data for GMS, STM, DRG, and CVS from January 2007 to February, 2016. Tobacco is not included.
Figure 3: Barcode-level Price and Quantity (Continuing Goods)
Figure 4: Unit Value Price and Volume × Quantity (All Goods)
Figure 5: Comparison of the Change in Quantity between Barcode- and Producer-level Estimates
Table 2: Estimation Results for Demand and Supply Elasticities

<table>
<thead>
<tr>
<th>Specifications</th>
<th>Barcode Level</th>
<th>Producer Level</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(1)</td>
<td>(2)</td>
</tr>
<tr>
<td>Number of Categories:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Achieving Convergence</td>
<td>995</td>
<td>937</td>
</tr>
<tr>
<td>For Which the Signs of $\sigma$ and $\omega$ Are Consistent with the Model</td>
<td>913</td>
<td>837</td>
</tr>
<tr>
<td>That Pass Overidentifying Restrictions</td>
<td>173</td>
<td>342</td>
</tr>
<tr>
<td>Basic Statistics for $\sigma$ and $\omega$:</td>
<td>Mean</td>
<td>11.48</td>
</tr>
<tr>
<td></td>
<td>Min</td>
<td>0.53</td>
</tr>
<tr>
<td></td>
<td>Max</td>
<td>308.07</td>
</tr>
<tr>
<td></td>
<td>Std. Dev.</td>
<td>14.70</td>
</tr>
<tr>
<td></td>
<td>Skew</td>
<td>15.05</td>
</tr>
<tr>
<td></td>
<td>Kurt</td>
<td>277.27</td>
</tr>
<tr>
<td></td>
<td>p10</td>
<td>5.59</td>
</tr>
<tr>
<td></td>
<td>p50</td>
<td>9.99</td>
</tr>
<tr>
<td></td>
<td>p90</td>
<td>15.69</td>
</tr>
</tbody>
</table>
Median for Estimated $\sigma$ and $\omega$

<table>
<thead>
<tr>
<th>Barcode Level</th>
<th>Producer Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\sigma$</td>
<td>9.99</td>
</tr>
<tr>
<td>$\omega$</td>
<td>5.36</td>
</tr>
<tr>
<td>$\sigma$</td>
<td>6.96</td>
</tr>
<tr>
<td>$\omega$</td>
<td>4.10</td>
</tr>
</tbody>
</table>
Figure 7: Demand and Supply Shocks Using Barcode-level Data

Note: The estimation is for the 797 categories that had signs for $\sigma$ and $\omega$ that were consistent with the model. The categories included in this figure are the same as in Figures 8 and 9. Tobacco is not included.
Figure 8: Demand and Supply Shocks Based on All Commodities

Note: The categories included in this figure are the same as those in Figures 7 and 9.
Figure 9: Comparisons of the Aggregate Demand and Supply Shocks

Note: The categories included in this figure are the same as those in Figures 7 and 8.
Time-varying Elasticities

We relax the assumption for demand elasticities in equation (1) such that they may be time variant.

\[
\ln(x_t^i) = \ln(C_t^i) + \sigma_t \ln(a_t^i) - \sigma_t \left( \ln(p_t^i) - \ln(P_t^i) \right)
\]

We assume that \( \sigma_t \) is a random walk as follows:

\[
\sigma_t = \sigma_{t-1} + \nu_t, \text{ where } \nu_t \text{ is i.i.d.}
\]

Taking time differences into account, we obtain:

\[
\Delta \ln x_t^i = \Delta \ln C_t^i - \sigma_{t-1} \left( \Delta \ln p_t^i - \Delta \ln P_t^i \right) - \nu_t \left( \ln p_t^i - \ln P_t^i \right) + \varepsilon_t^i \tag{5}
\]

where \( \varepsilon_t^i = (\sigma_{t-1} + \nu_t) \ln a_t^i - \sigma_{t-1} \ln a_{t-1}^i. \)
Furthermore, taking the difference from the average of the same producer leads to:

\[ \Delta \ln x_t^i - \bar{\Delta \ln x_t^i} = \varepsilon_t^i - \bar{\varepsilon_t^i} - \sigma_{t-1} (\Delta \ln p_t^i - \bar{\Delta \ln p_t^i}) - \nu_t (\ln p_t^i - \bar{\ln p_t^i}) \]  \hspace{1cm} (6)

To control for the store-level effects on the price level, we construct store effects, defined as follows:

\[ K_{m,s}^{\text{year}} = \frac{1}{\#(\Theta_{m,s}^{\text{year}})} \sum_{i \in m,s,\text{year}} (\ln p_t^i - \bar{\ln p_t^i}) \]

where \#(\Theta_{m,s}^{\text{year}}) is the number of products included for producer \(m\), and for the store \(s\), in each year.
Estimation Procedure (1)

• We assume that the elasticities of supply vary less frequently than those of demand because time is required to increase or decrease production equipment.

• We use the estimated results on a year-by-year basis in specification (4) in Table 2 as the time-variant elasticities of the supply function.

• As $\sigma_{t-1}$ in equation (6) is known at time $t$, $\nu_t$ is the only parameter to be estimated.

$$\Delta \ln x_t^i - \Delta \ln x_t^i = \varepsilon_t^i - \bar{\varepsilon}_t^i - \sigma_{t-1} (\Delta \ln p_t^i - \Delta \ln p_t^i) - \nu_t (\ln p_t^i - \ln p_t^i)$$  \hspace{0.5cm} (6)

• We use the following three moment conditions.

$$E \left[ (\varepsilon_t^i - \bar{\varepsilon}_t^i) \left\{ (\Delta \ln x_t^i - \Delta \ln x_t^i) - \bar{\omega}_y (\Delta \ln p_t^i - \Delta \ln p_t^i - K_{m,s}^{year}) \right\} \right] = 0,$$

$$E \left[ (\varepsilon_t^i - \bar{\varepsilon}_t^i)^2 \left\{ (\Delta \ln x_t^i - \Delta \ln x_t^i) - \bar{\omega}_y (\Delta \ln p_t^i - \Delta \ln p_t^i - K_{m,s}^{year}) \right\} \right] = 0,$$

$$E \left[ (\varepsilon_t^i - \bar{\varepsilon}_t^i) \left\{ (\Delta \ln x_t^i - \Delta \ln x_t^i) - \bar{\omega}_y (\Delta \ln p_t^i - \Delta \ln p_t^i - K_{m,s}^{year}) \right\}^2 \right] = 0.$$
Assuming constant elasticity, using the sample for 2007, we obtain the estimate of $\sigma_0$.

2 Setting the initial value of $\sigma_0$.

3 Given $\sigma_{t-1}$, for each month,

- Updating the demand elasticity using $\sigma_t = \sigma_{t-1} + \nu_t$,

as long as the GMM results satisfy the following two conditions:

(a) the estimate of $\nu_t$ is statistically significant at the 10% level

(b) the overidentification test is passed at the 10% level.

If the two conditions are not satisfied, we retain the previous estimates, that is, $\sigma_t = \sigma_{t-1}$.

4 Calculating the entire squared sum of residuals for the entire sample period.

5 Changing the initial value $\sigma_0$

and repeat ② to find the initial value that minimizes the squared sum of residuals.
Figure 10: Changes in Estimates of Demand Elasticities

Note: 1) These estimates are for 336 categories, which have signs consistent with the model for $\sigma$ and $\omega$ and which pass the overidentification restrictions. 2) The weighted average is calculated on the basis of sales volumes for each category.
Figure 11: Demand and Supply Shocks with Time-varying Elasticity

Note: These estimates are for 336 categories, which have signs consistent with the model for $\sigma$ and $\omega$ and which pass the overidentification restrictions.
Note: These estimates are for 336 categories, which have signs consistent with the model for $\sigma$ and $\omega$ and which pass the overidentification restrictions.
Comparisons with Traditional Methods of Estimating AS-AD Shocks
Traditional AD-AS Shocks


Supply Shocks: Affect the long run real GDP
Demand Shocks: Do not affect long run real GDP, but affect nominal variable.

- GDP gap: Estimating potential GDP and taking the difference between the actual GDP and the potential GDP (Cabinet Office) or calculating the utilization rate of production factors (BOJ)

Supply Shock: Long run changes in production level
Demand Shock: Departure from the potential GDP
## Major Findings

<table>
<thead>
<tr>
<th>Period</th>
<th>Aggregate Demand Shocks</th>
<th>Aggregate Supply Shocks</th>
</tr>
</thead>
<tbody>
<tr>
<td>2007</td>
<td>positive</td>
<td>negative</td>
</tr>
<tr>
<td>2008</td>
<td>positive large</td>
<td>negative large</td>
</tr>
<tr>
<td>2009-2010</td>
<td>negative</td>
<td>positive</td>
</tr>
<tr>
<td>The Great East Japan Disaster</td>
<td>temporal positive</td>
<td>temporal negative</td>
</tr>
<tr>
<td>2011-2013</td>
<td>negative</td>
<td>positive</td>
</tr>
<tr>
<td>Before the increase in Tax</td>
<td>positive</td>
<td>zero</td>
</tr>
<tr>
<td>late 2013-present</td>
<td>positive</td>
<td>negative</td>
</tr>
</tbody>
</table>

[Figure 8]
Recent Macroeconomic Events

- In this framework, the change in consumption tax rate does not change the relative prices within category or stores.
- It does have an effect through changes in real income, Ct.
- Demand Elasticities are rising, but do not have significant effects on our estimates of AD and AS shocks.
- The inward shifts of supply curve, probably caused by depreciation in yen, came along with upward shifts in demand curve, keeping the quantity constant, while prices going up.
Remaining Tasks

• Causes of the shocks (exchange rate, oil-material prices, wage, import and export, subsidy, etc.)

• Utilizing category specific, area specific information

• More detailed comparisons with the traditional approach

• If possible, relaxing assumptions of CES (Is AIDS possible?)
Comparisons with Official CPI
Official CPI and UVP with all the continuing goods

(y/y change rate)
Official CPI and UVP including new goods
Official CPI and UVPs