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Estimation of Aggregate Demand and Supply Shocks Using Commodity Transaction Data

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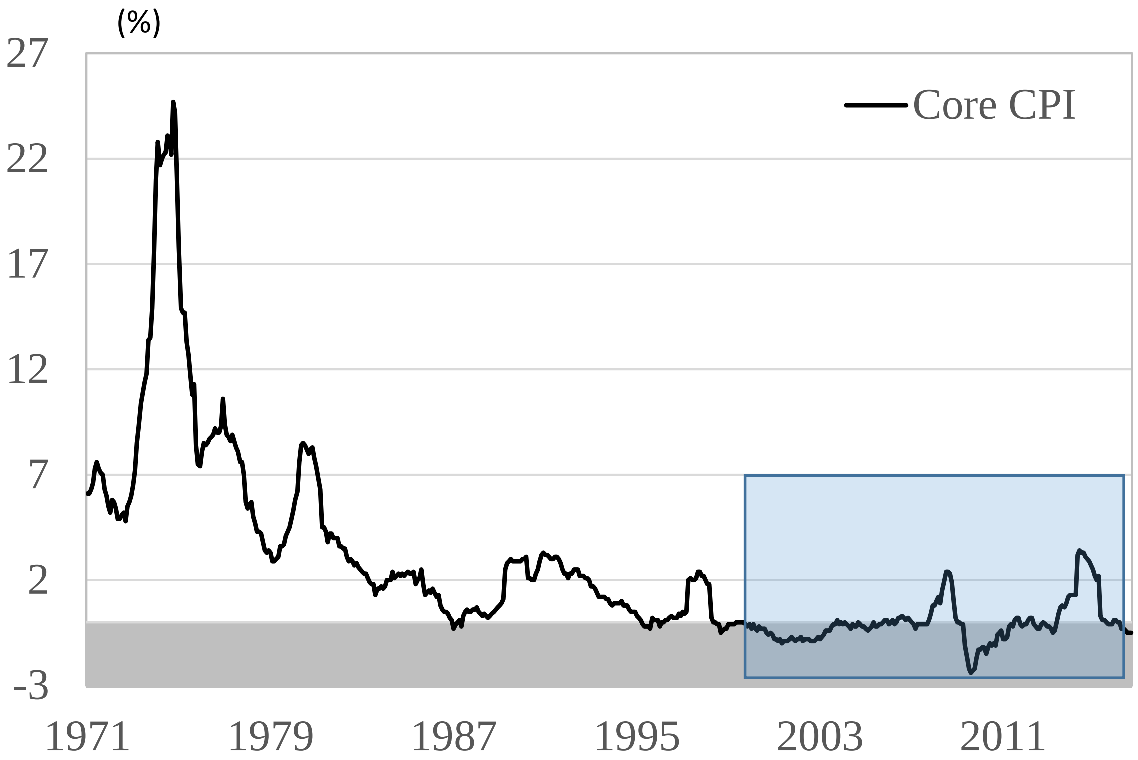
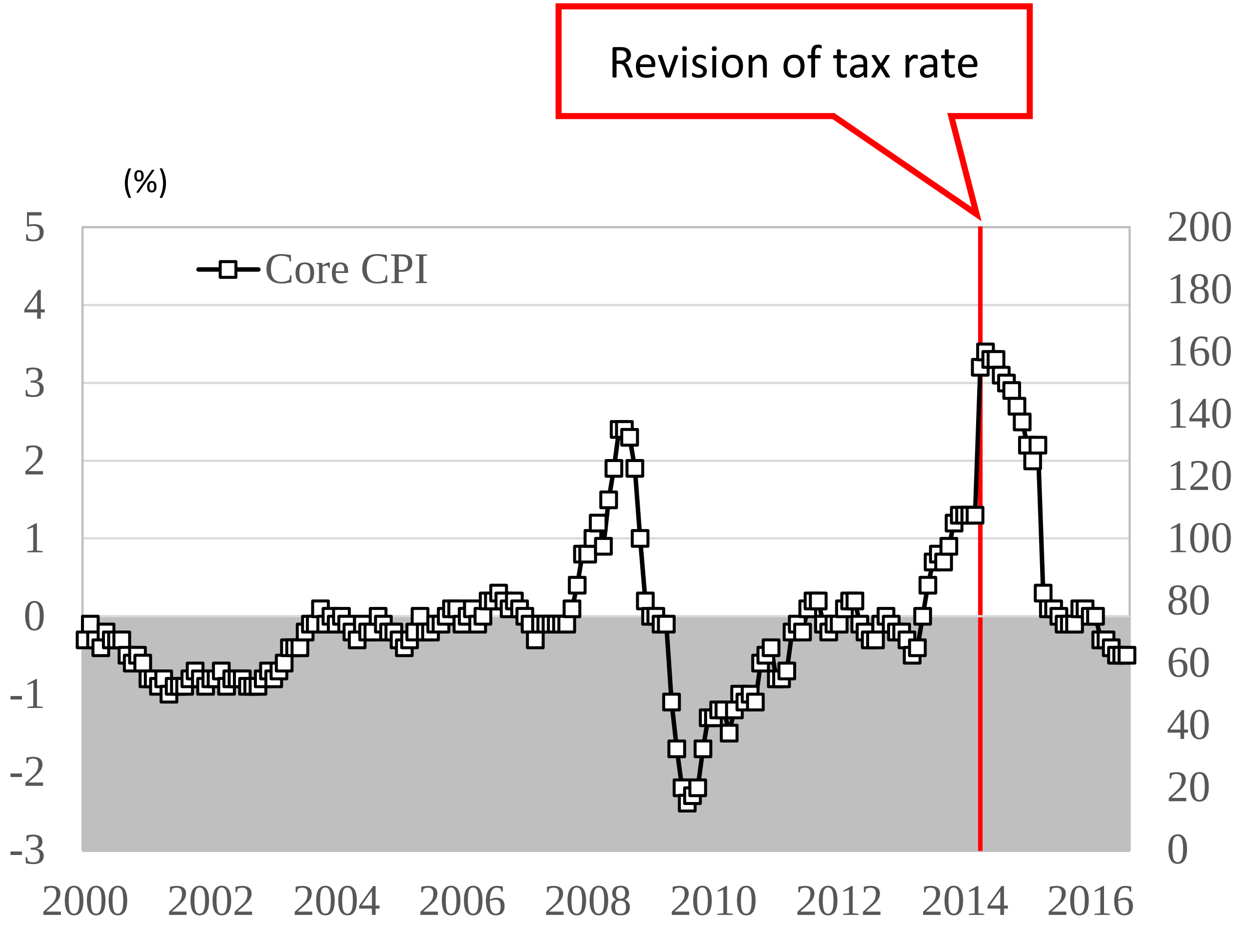
Consumer Price Index in Japan





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.

Identification of Demand and Supply Curve

- 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

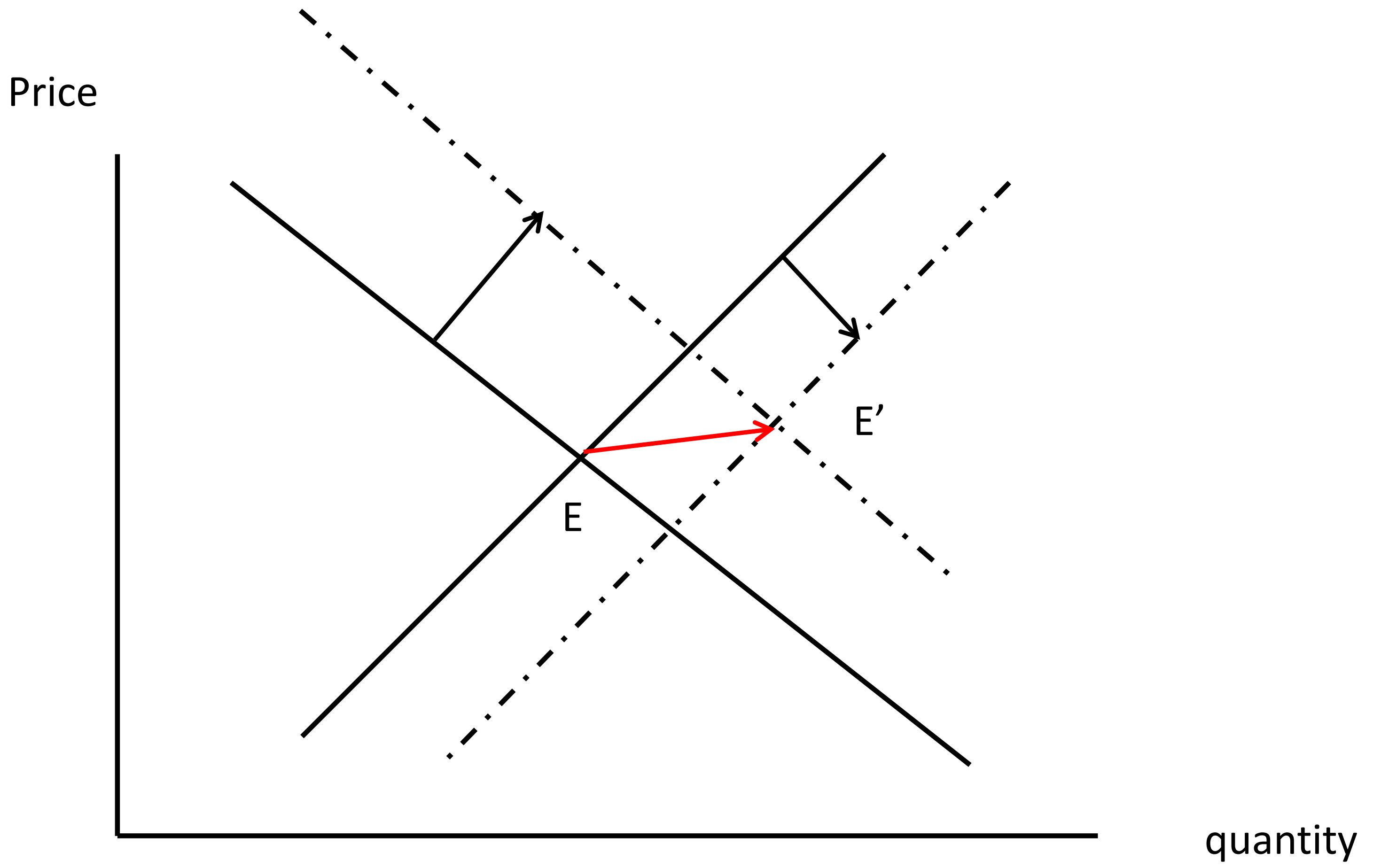
- Good Point: timely estimate, weak theory requirements
- Bad Point: service, durable, fresh foods not included

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.

Intuition



Given demand and supply curves, we can uniquely decompose the movements of price and quantity into (1) demand and (2) supply shock.

Model

The representative consumer has the following separable utility function at time t:

$$U_t = U\left(C_t^1, C_t^2, \dots, C_t^J\right),$$

$$C_t^j = \left(\sum_{i \in \Theta_t^j} a_t^i \, x_t^{i\,\frac{\sigma_j - 1}{\sigma_j}}\right)^{\frac{\sigma_j}{\sigma_j - 1}}, \qquad a_t^i \geq 0, \qquad , \sigma_j > 0$$

x_t^i : consumption of commodity *i* at time *t*.

Θ_t^j : the commodity space of category *j* at time *t*

C_t^j : the aggregate consumption of category *j* at time *t*

a_t^i : 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:

$$x_t^i = \mathrm{C}_\mathrm{t}^j \left(\sum_{k \in \Theta_t^j} {a_t^k}^{\sigma_j} {p_t^k}^{1-\sigma_j} \right)^{\frac{\sigma_j}{1-\sigma_j}} {a_t^i}^{\sigma} {p_t^i}^{-\sigma_j}.$$

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:

$$\Delta \mathrm{l\,n}(x_t^i) = \Delta \ln\left(C_t^j\right) - \sigma_j \, \Delta \ln\left(p_t^i\right) + \sigma_j \, \Delta \ln\left(P_t^j\right) + \varepsilon_t^i \qquad (1)$$

commodity specific shock

$$\Delta \ln(x_t^i) = \Delta \ln(C_t^j) - \sigma_j \, \Delta \ln(p_t^i) + \sigma_j \, \Delta \ln(P_t^j) + \varepsilon_t^i \quad \text{, where } \varepsilon_t^i = \sigma_j \, \Delta \ln(a_t^i).$$

category specific Income Effects (macroeconomic Income Shock)

the effects of the relative prices

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:

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

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

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

where $\#\left(\Theta_t^{j,b}\right)$ is the number of products included in the product set

for the barcode *b*, $\Theta_t^{j,b}$.

For simplification, denote

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

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

Then, the demand equation becomes,

$$\tilde{x}_t^i = -\sigma_j \, \tilde{p}_t^i + \tilde{\varepsilon}_t^i. \qquad (2)$$

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

$$\Delta \ln(x_t^i) = \omega_j \Delta \ln(p_t^i) + S_t^j + \delta_t^i \qquad (3)$$

ω_j : constant parameter

δ_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:

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

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

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

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

$$\tilde{x}_t^i = \omega_j \tilde{p}_t^i + \tilde{\delta}_t^i \qquad (4)$$

Identification

- Our main identification assumption for estimating the elasticities, σ_j and ω_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.

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

$$\mathrm{E}\left[{\tilde{\delta}_t^i}^2 \tilde{\varepsilon}_t^i\right] = 0$$

$$\mathrm{E}\left[\tilde{\delta}_t^i {\tilde{\varepsilon}_t^i}^2\right] = 0$$

- 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, $(\hat{\sigma}, \widehat{\omega})$, we plug them into (1) and (3), which gives us the following two sets of shocks:

$$\hat{\varepsilon}_t^i \equiv \Delta \ln(x_t^i) + \hat{\sigma} \Delta \ln(p_t^i)$$

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

$$\hat{\varepsilon}_t^i \equiv \Delta \ln(x_t^i) + \hat{\sigma}\Delta \ln(p_t^i)$$

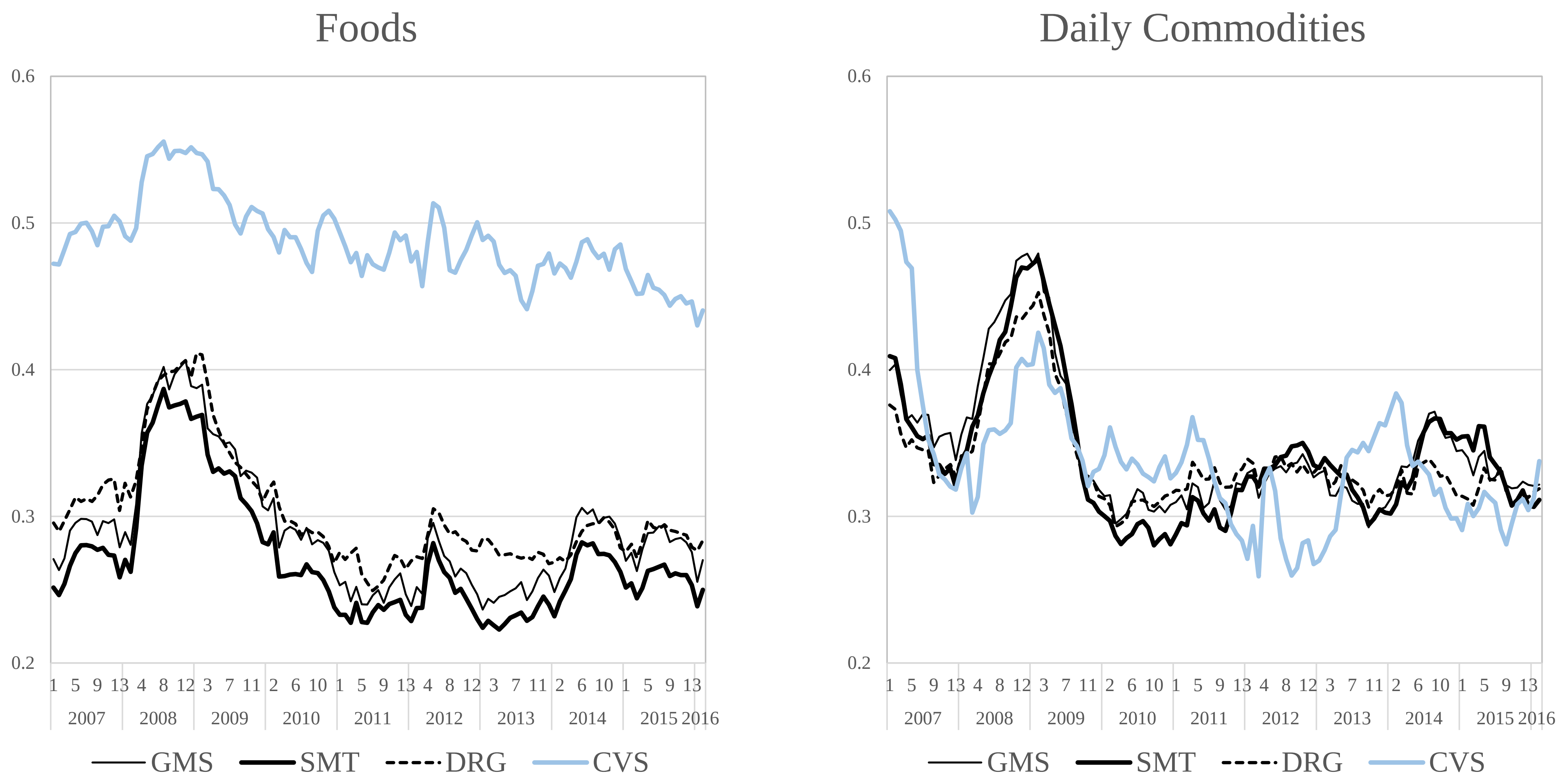
$$\hat{\delta}_t^i \equiv \Delta \ln(x_t^i) - \hat{\omega}\Delta \ln(p_t^i)$$

- $\hat{\varepsilon}_t^i$ 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)



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.

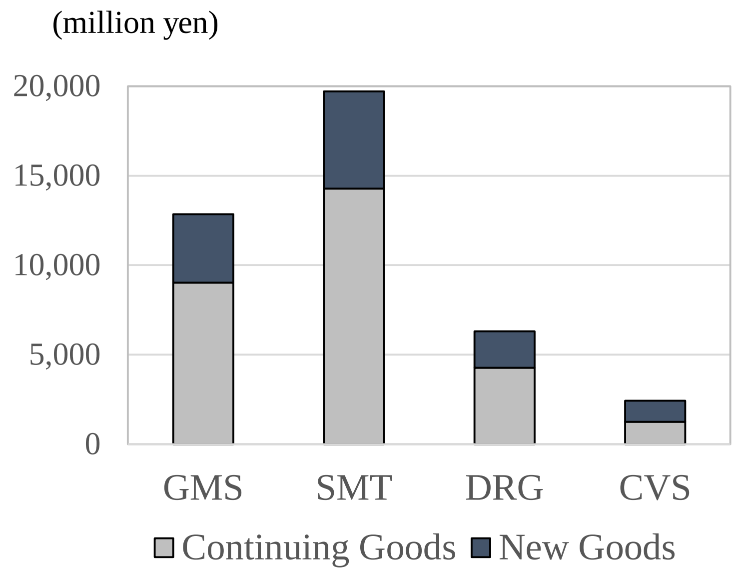
Detailed Commodity Classification

We use category 2 level product classifications.

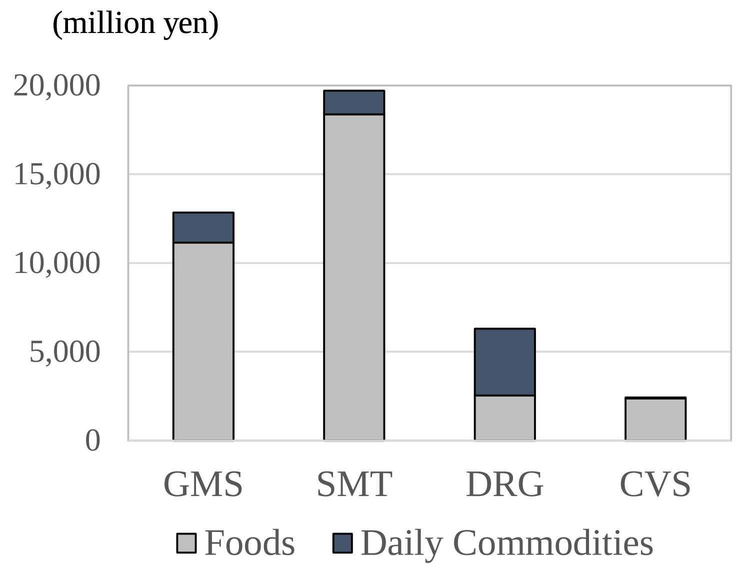
Category 1	Category 2
Laundry detergent	Powder / Highly concentrated
	Powder / concentrated
	Powder / Non-concentrated
	Liquid / Highly concentrated
	Liquid / concentrated
	Liquid/ Non-concentrated
	Others

Summary of Monthly Transaction Data (1)

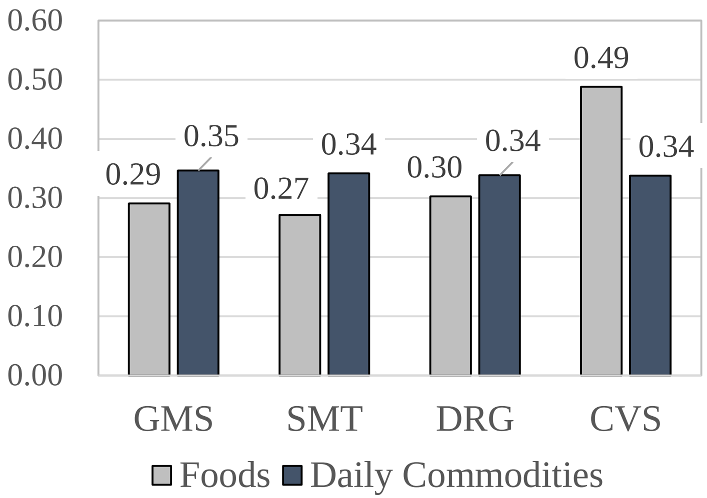
(1) Volume of Sales (Continuing vs. New Goods)



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

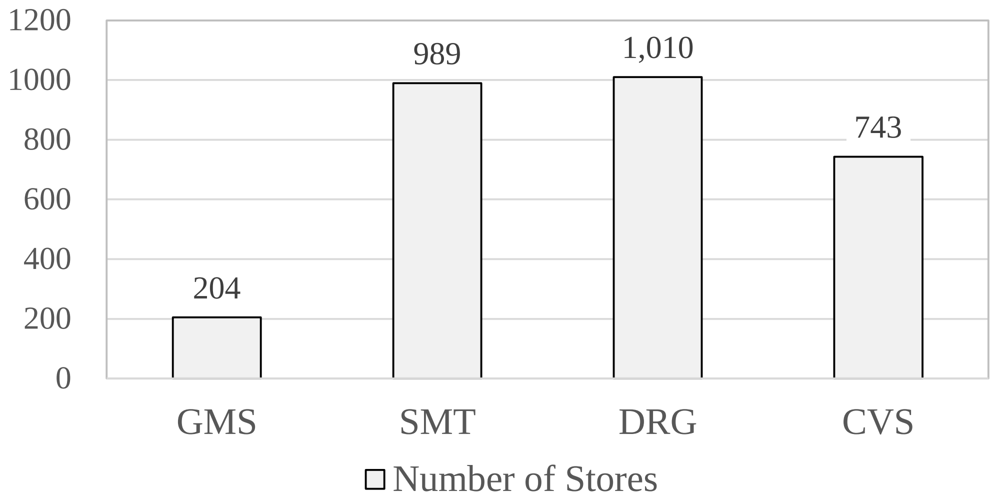


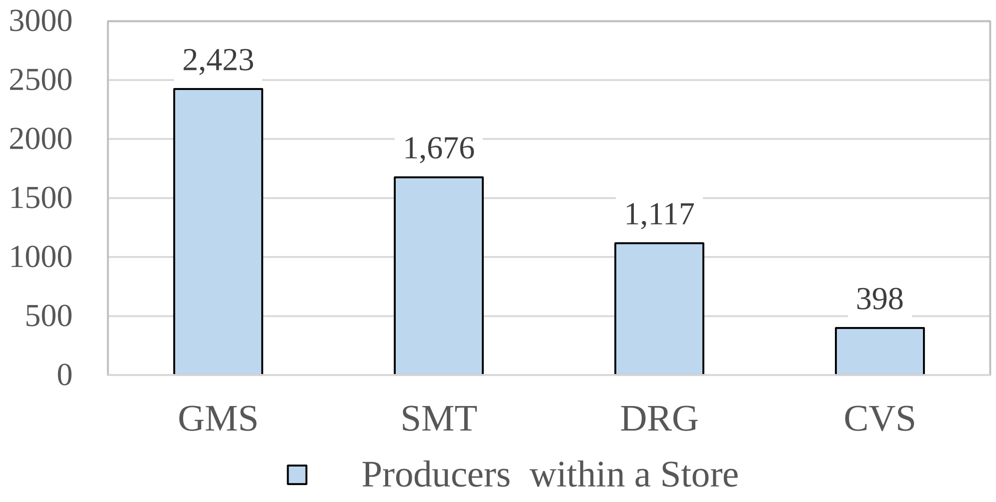
(3) New Product Ratio (Food vs. Daily Commodities)

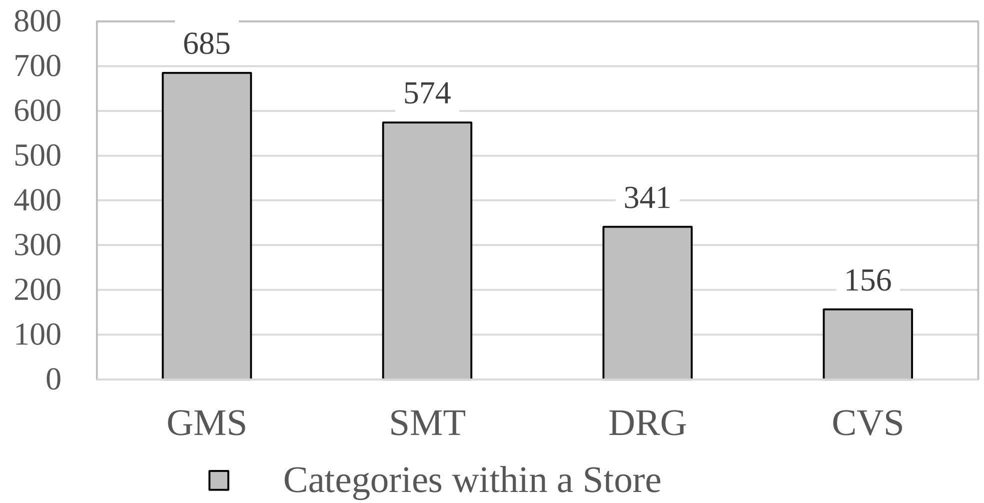


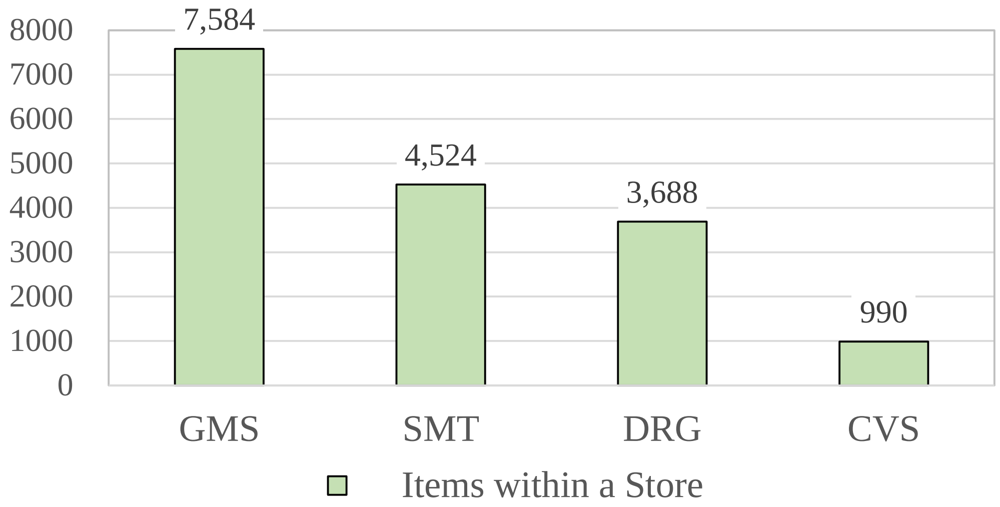
Note: Monthly point of sale data for GMS, STM, DRG, and CVS from January 2007 to February, 2016. Tobacco is not included.

Summary of Monthly Transaction Data (2)









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)

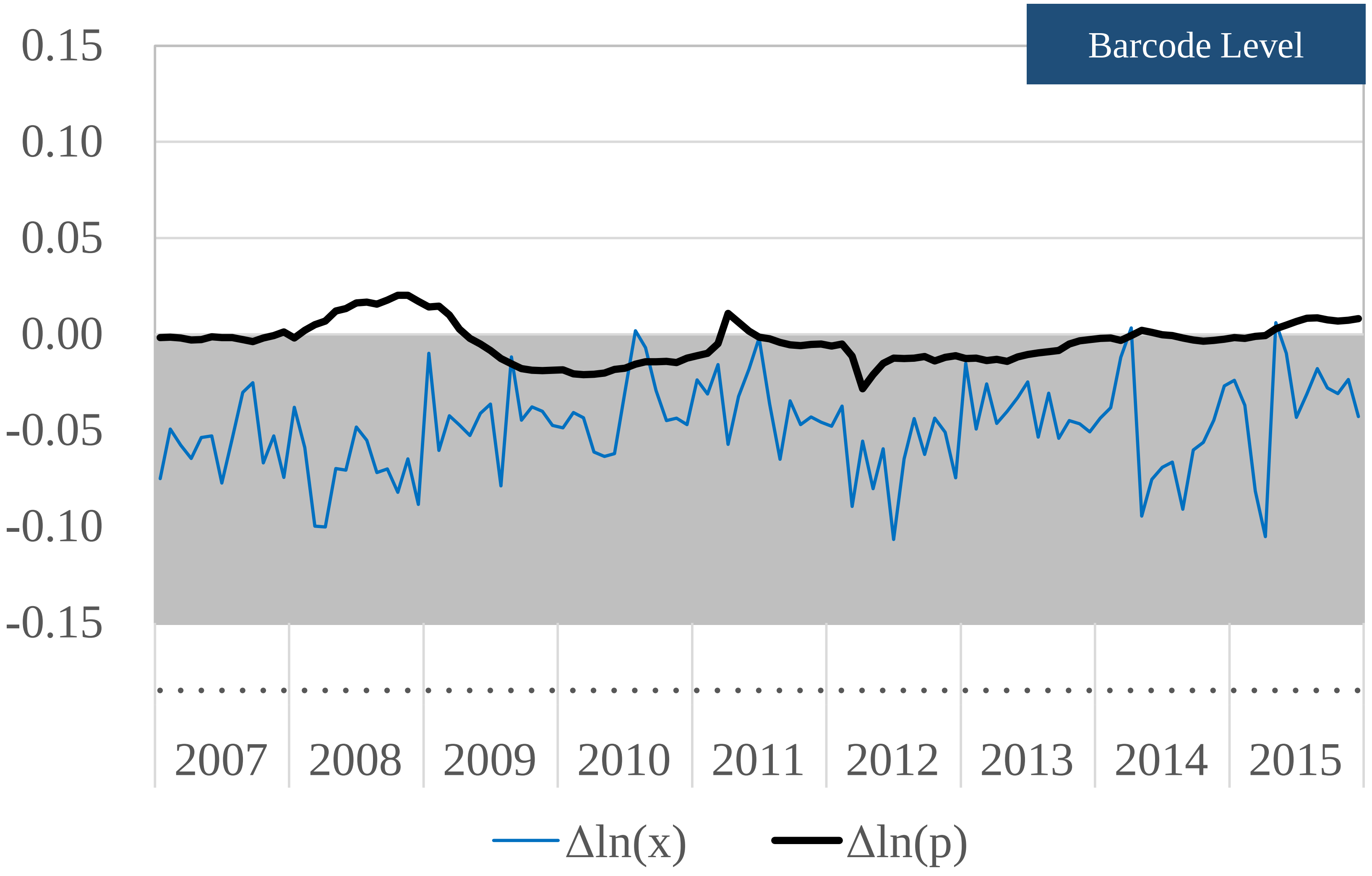


Figure 4: Unit Value Price and Volume × Quantity (All Goods)

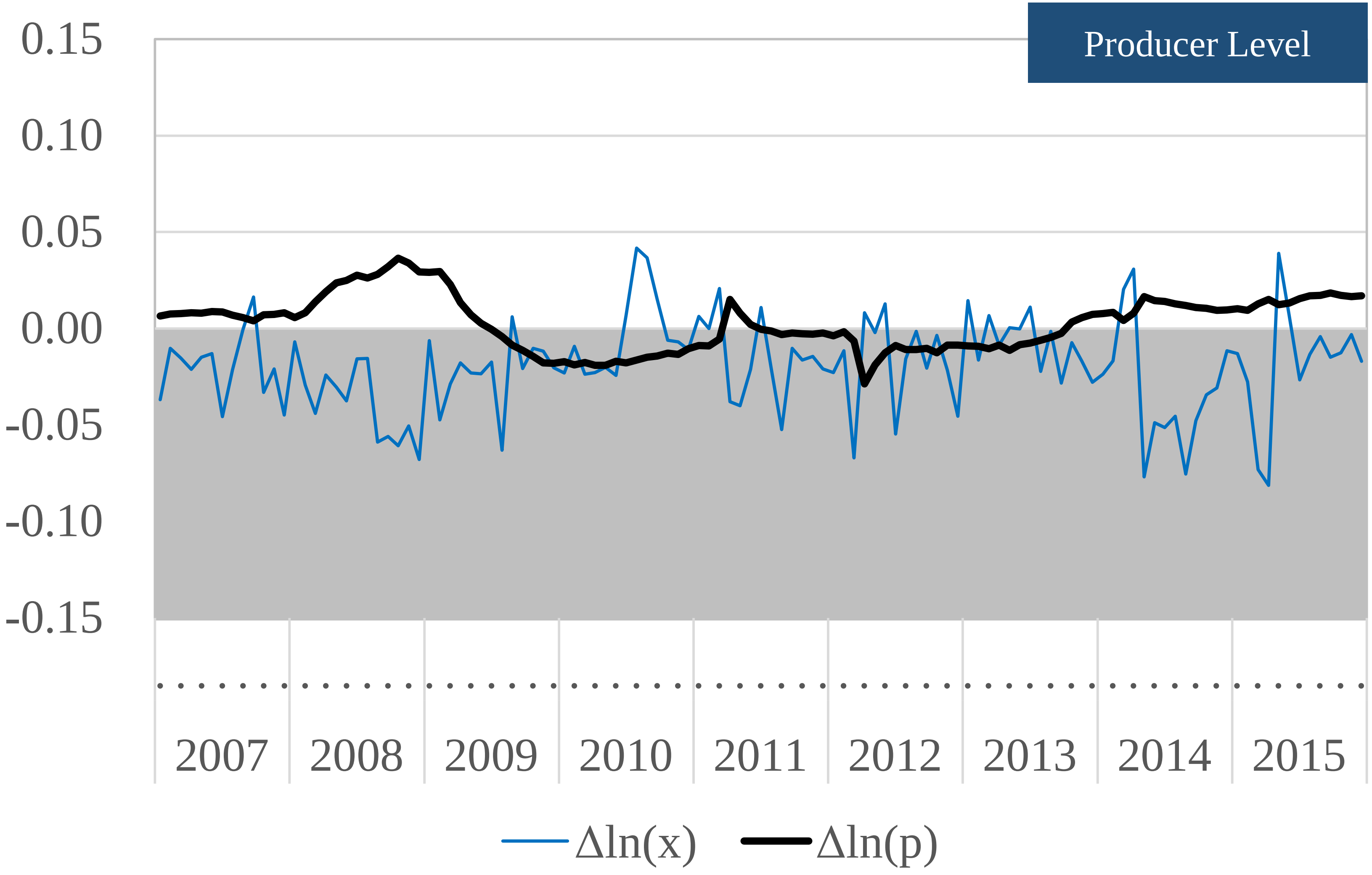
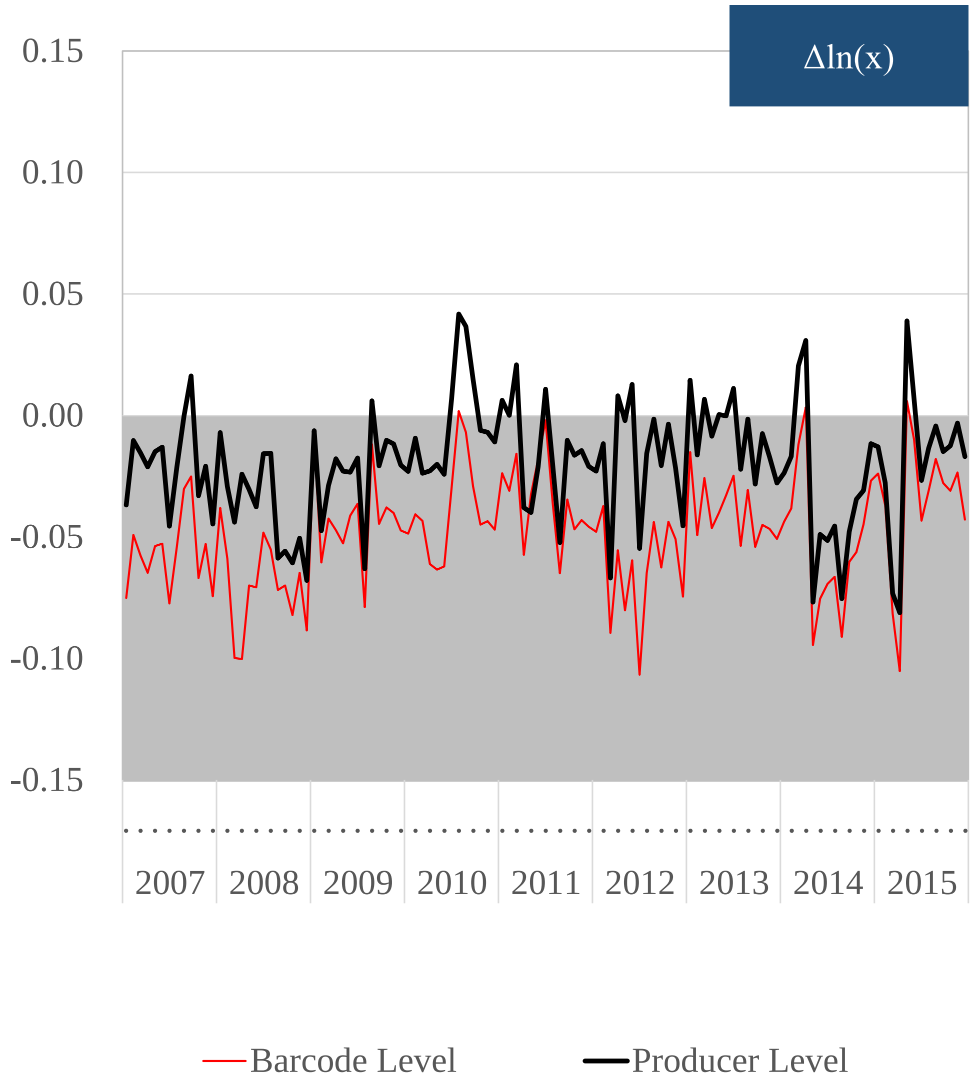


Figure 5: Comparison of the Change in Quantity between Barcode- and Producer-level Estimates



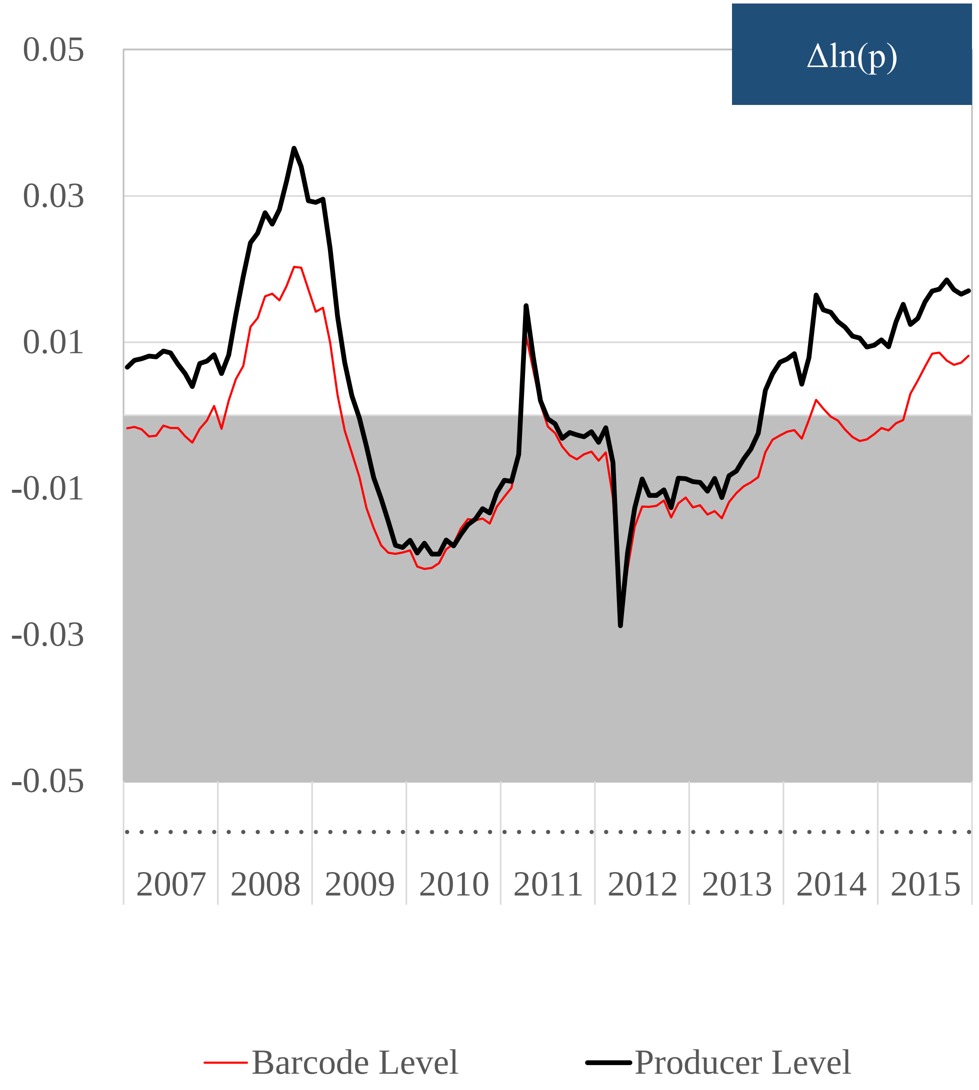


Table 2: Estimation Results for Demand and Supply Elasticities

	Barcode Level (continuing goods only)				Producer Level (including new goods)			
Specifications	(1)		(2)		(3)		(4)	
Data Period	2007M1－2016M2		2007 only		2007M1－2016M2		2007 only	
Number of Categories:								
Achieving Convergence	995		937		1007		931	
For Which the Signs of σ and ω Are Consistent with the Model	913		837		897		819	
That Pass Overidentifying Restrictions	173		342		351		425	
Basic Statistics for σ and ω:	σ	ω	σ	ω	σ	ω	σ	ω
Mean	11.48	8.43	14.67	10.39	8.28	7.01	11.61	6.90
Min	0.53	0.00	0.60	0.01	0.65	0.00	0.78	0.00
Max	308.07	516.36	797.57	823.76	138.29	723.62	1291.64	198.03
Std. Dev.	14.70	25.43	32.29	33.74	8.09	26.19	48.08	13.36
Skew	15.05	14.44	18.32	18.04	8.20	23.41	23.60	7.54
Kurt	277.27	243.03	421.96	411.48	104.88	628.86	617.63	79.27
p10	5.59	1.99	4.58	1.52	3.38	1.10	3.08	0.88
p50	9.99	5.36	10.31	5.49	6.96	4.10	7.02	3.86
p90	15.69	11.61	22.10	16.69	12.52	10.88	15.95	13.14

Median for Estimated σ and ω

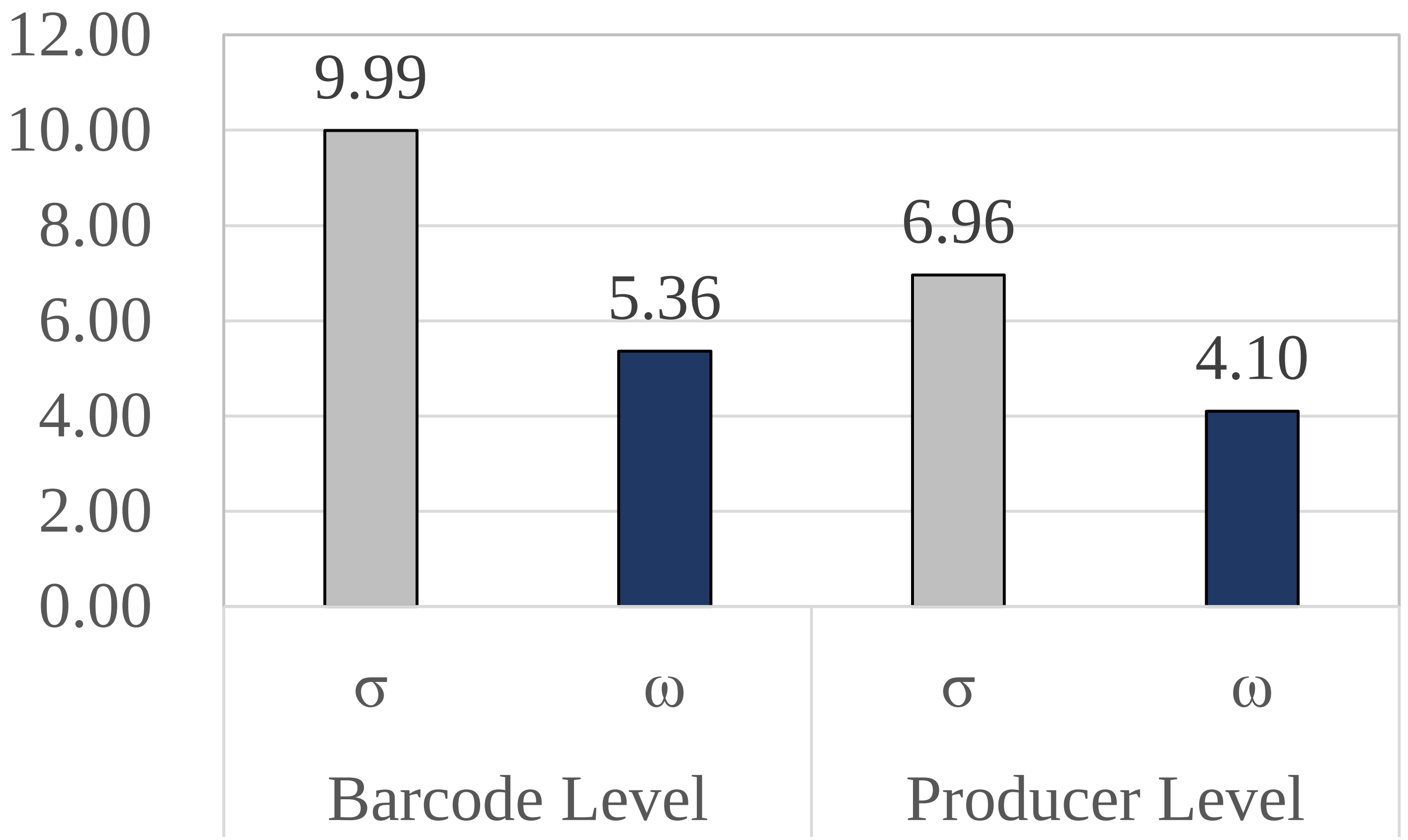
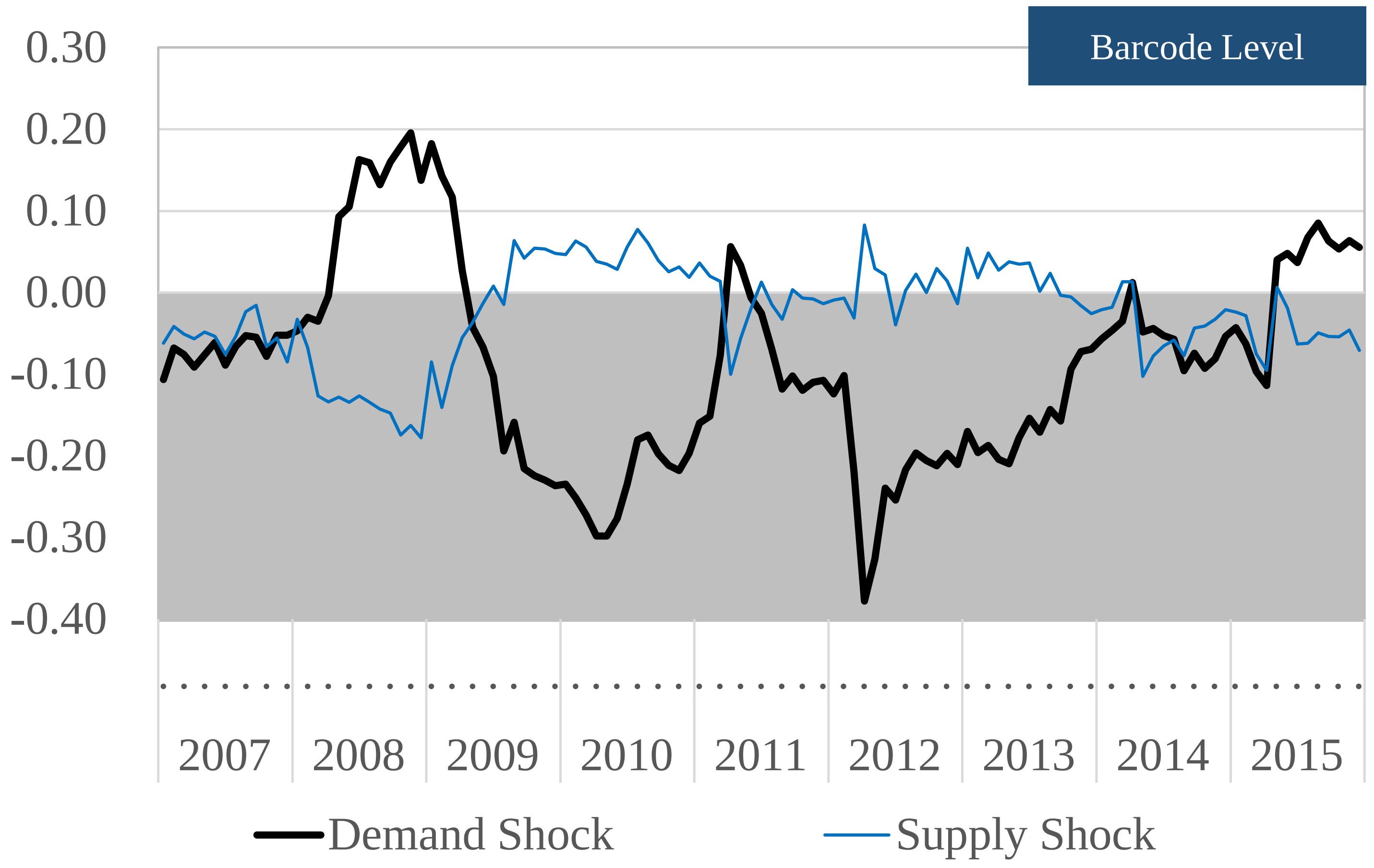
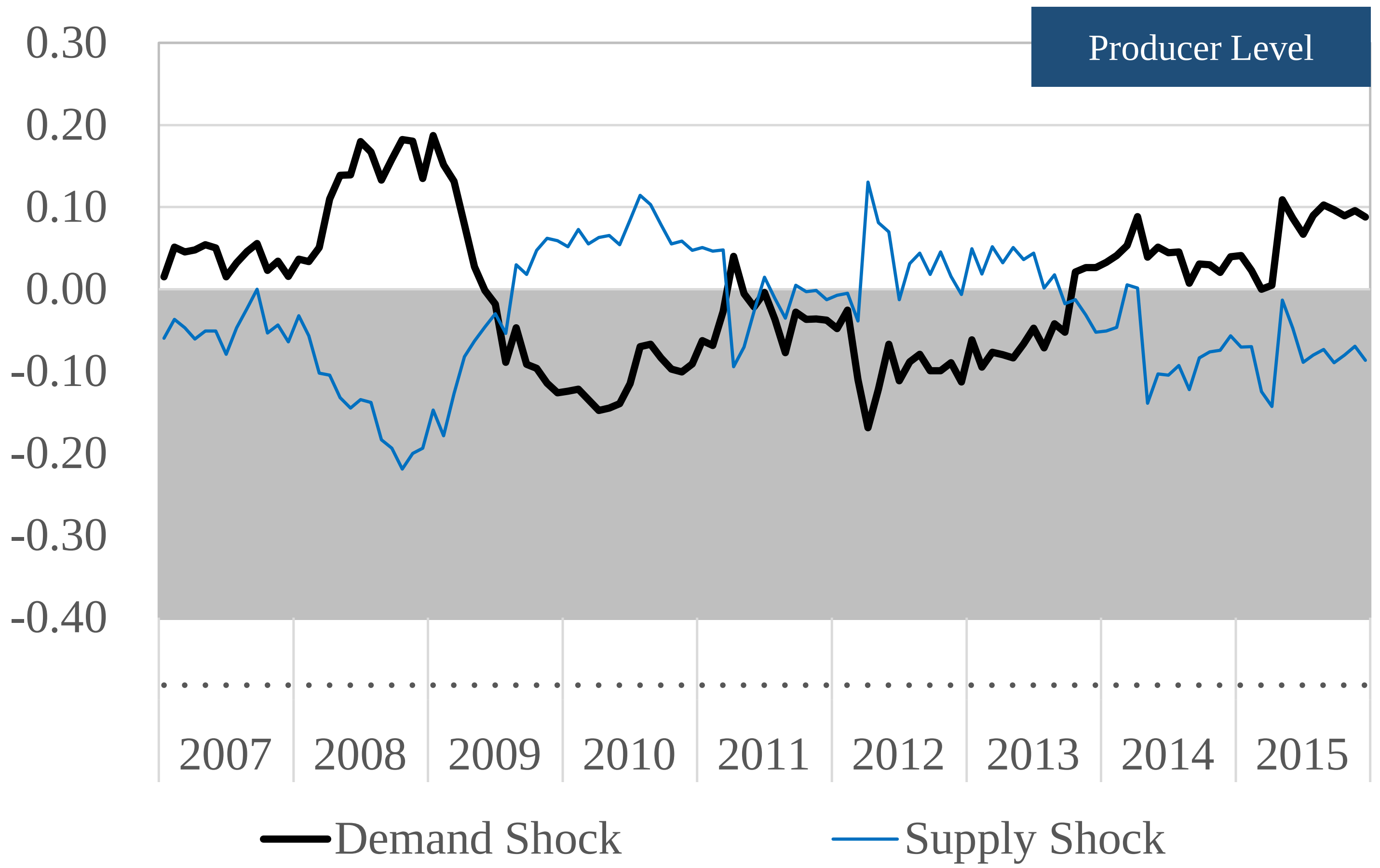


Figure 7: Demand and Supply Shocks Using Barcode-level Data



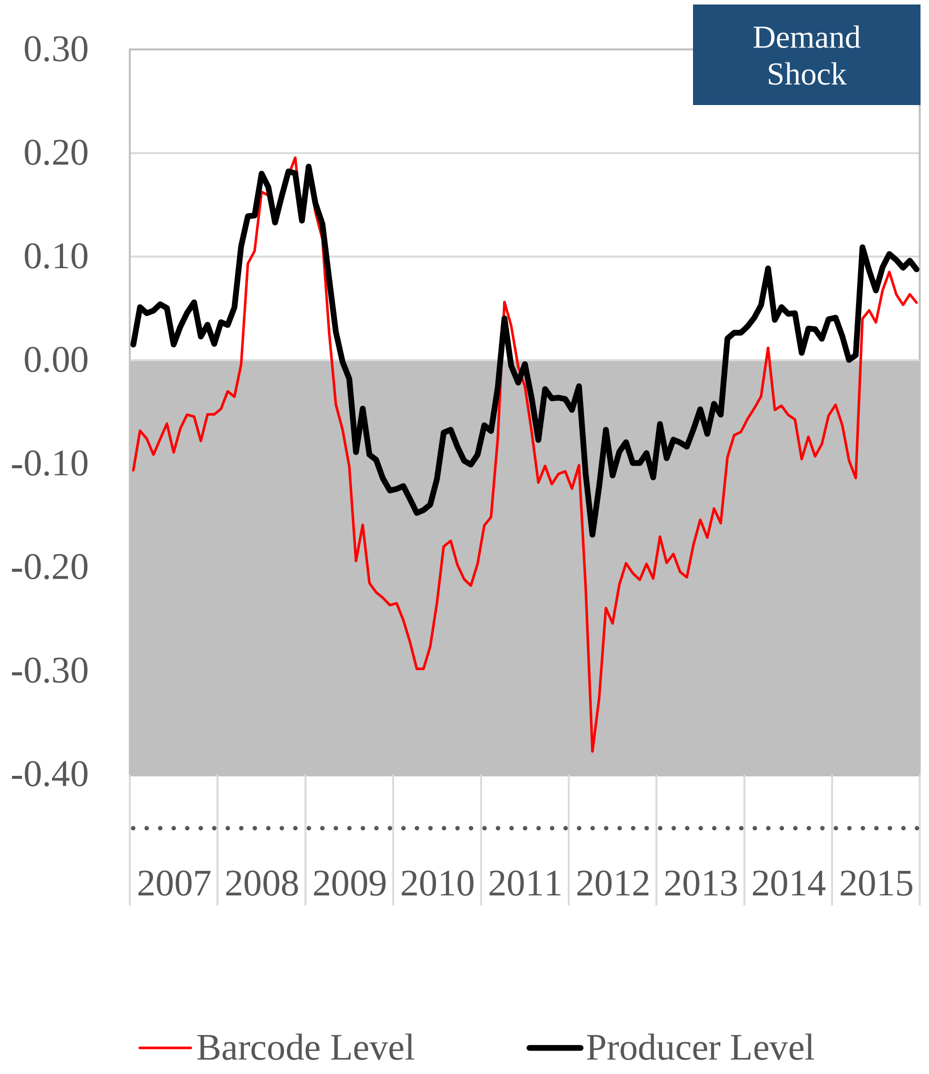
Note: The estimation is for the 797 categories that had signs for σ and ω that were consistent with the model. The categories included in this figure are the same as in Figures 8 and 9. Tobacco is not included.

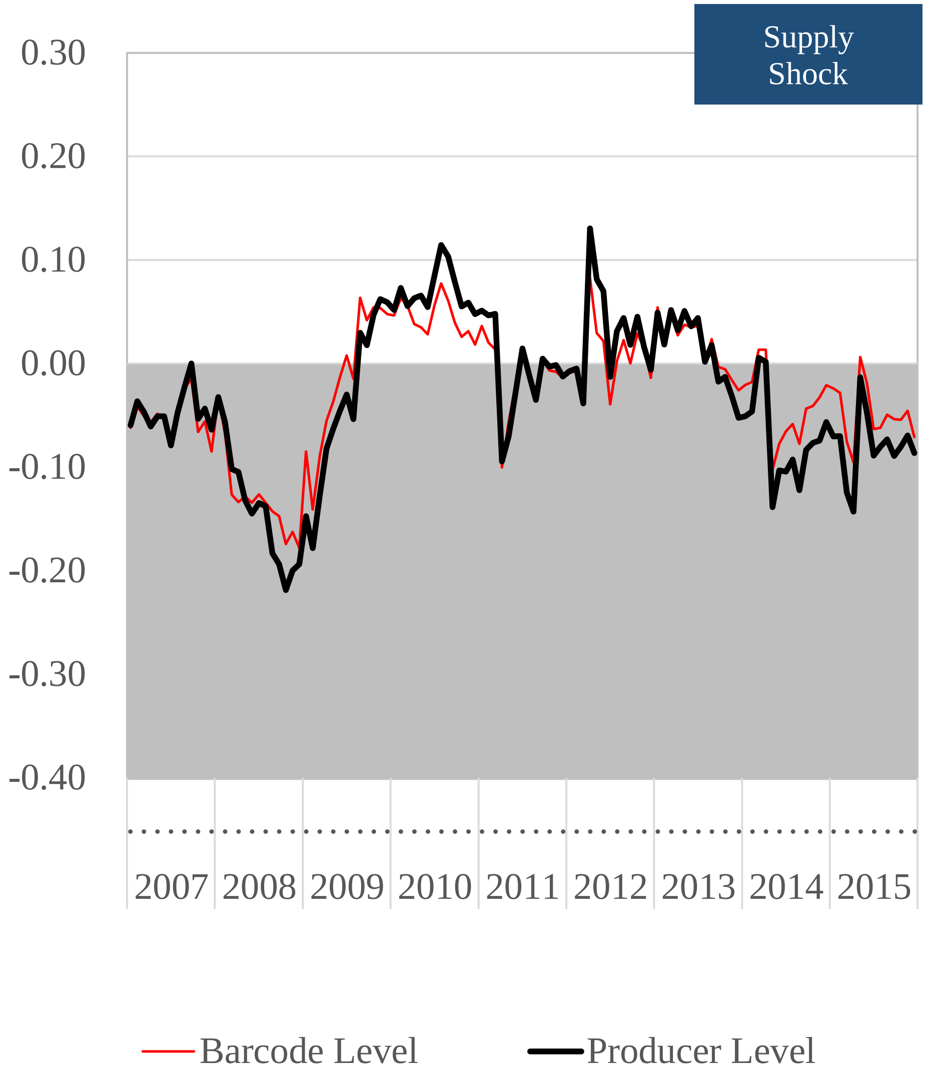
Figure 8: Demand and Supply Shocks Based on All Commodities



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.

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

We assume that σ_t is a random walk as follows:

$$\sigma_t = \sigma_{t-1} + v_t, \text{ where } v_t \text{ is i.i.d.}$$

Taking time differences into account, we obtain:

$$\Delta \ln x_t^i = \Delta \ln C_t^i - \sigma_{t-1}\left(\Delta \ln p_t^i - \Delta \ln P_t^i\right) - v_t\left(\ln p_t^i - \ln P_t^i\right) + \varepsilon_t^i \qquad (5)$$

where $\varepsilon_t^i = (\sigma_{t-1} + v_t)\ln a_t^i - \sigma_{t-1}\ln a_{t-1}^i$.

Furthermore, taking the difference from the average of the same producer leads to:

$$\Delta \ln x_t^i - \overline{\Delta \ln x_t^i} = \varepsilon_t^i - \overline{\varepsilon_t^i} - \sigma_{t-1}\left(\Delta \ln p_t^i - \overline{\Delta \ln p_t^i}\right) - \nu_t \left(\ln p_t^i - \overline{\ln p_t^i}\right) \qquad (6)$$

difference of the price levels among different stores

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

$$K_{year}^{m,s} = \frac{1}{\#\left(\Theta_{year}^{m,s}\right)} \sum_{i \in m,s,year} \left(\ln p_t^i - \overline{\ln p_t^i}\right)$$

where $\#\left(\Theta_{year}^{m,s}\right)$ 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 σ_{t-1} in equation (6) is known at time t, ν_t is the only parameter to be estimated.

$$\Delta \ln x_t^i - \overline{\Delta \ln x_t^i} = \varepsilon_t^i - \overline{\varepsilon_t^i} - \sigma_{t-1}\left(\Delta \ln p_t^i - \overline{\Delta \ln p_t^i}\right) - \nu_t\left(\ln p_t^i - \overline{\ln p_t^i}\right) \qquad (6)$$

- We use the following three moment conditions.

$$\mathrm{E}\left[\left(\varepsilon_t^i - \overline{\varepsilon_t^i}\right)\left\{\left(\Delta \ln x_t^i - \overline{\Delta \ln x_t^i}\right) - \widehat{\omega_y}\left(\Delta \ln p_t^i - \overline{\Delta \ln p_t^i} - K_{year}^{m,s}\right)\right\}\right] = 0,$$

$$\mathrm{E}\left[\left(\varepsilon_t^i - \overline{\varepsilon_t^i}\right)^2\left\{\left(\Delta \ln x_t^i - \overline{\Delta \ln x_t^i}\right) - \widehat{\omega_y}\left(\Delta \ln p_t^i - \overline{\Delta \ln p_t^i} - K_{year}^{m,s}\right)\right\}\right] = 0,$$

$$\mathrm{E}\left[\left(\varepsilon_t^i - \overline{\varepsilon_t^i}\right)\left\{\left(\Delta \ln x_t^i - \overline{\Delta \ln x_t^i}\right) - \widehat{\omega_y}\left(\Delta \ln p_t^i - \overline{\Delta \ln p_t^i} - K_{year}^{m,s}\right)\right\}^2\right] = 0.$$

Estimation Procedure(2)

① Assuming constant elasticity, using the sample for 2007, we obtain the estimate of σ_0.

② Setting the initial value of σ_0.

③ Given σ_{t-1}, for each month,

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

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

(a) the estimate of ν_t is statistically significant at the 10% level

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

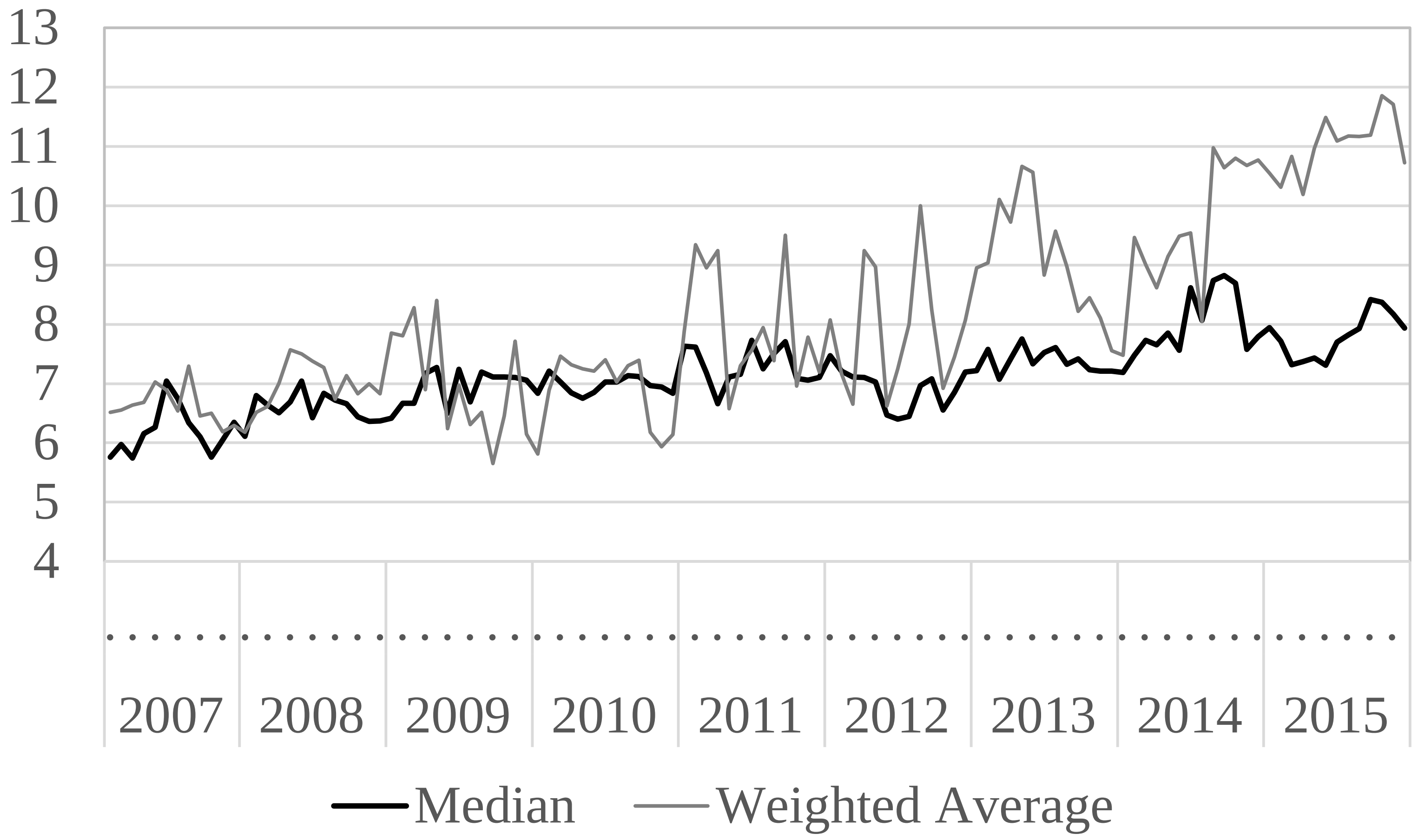
If the two conditions are not satisfied, we retain the previous estimates, that is, $\sigma_t = \sigma_{t-1}$.

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

⑤ Changing the initial value σ_0

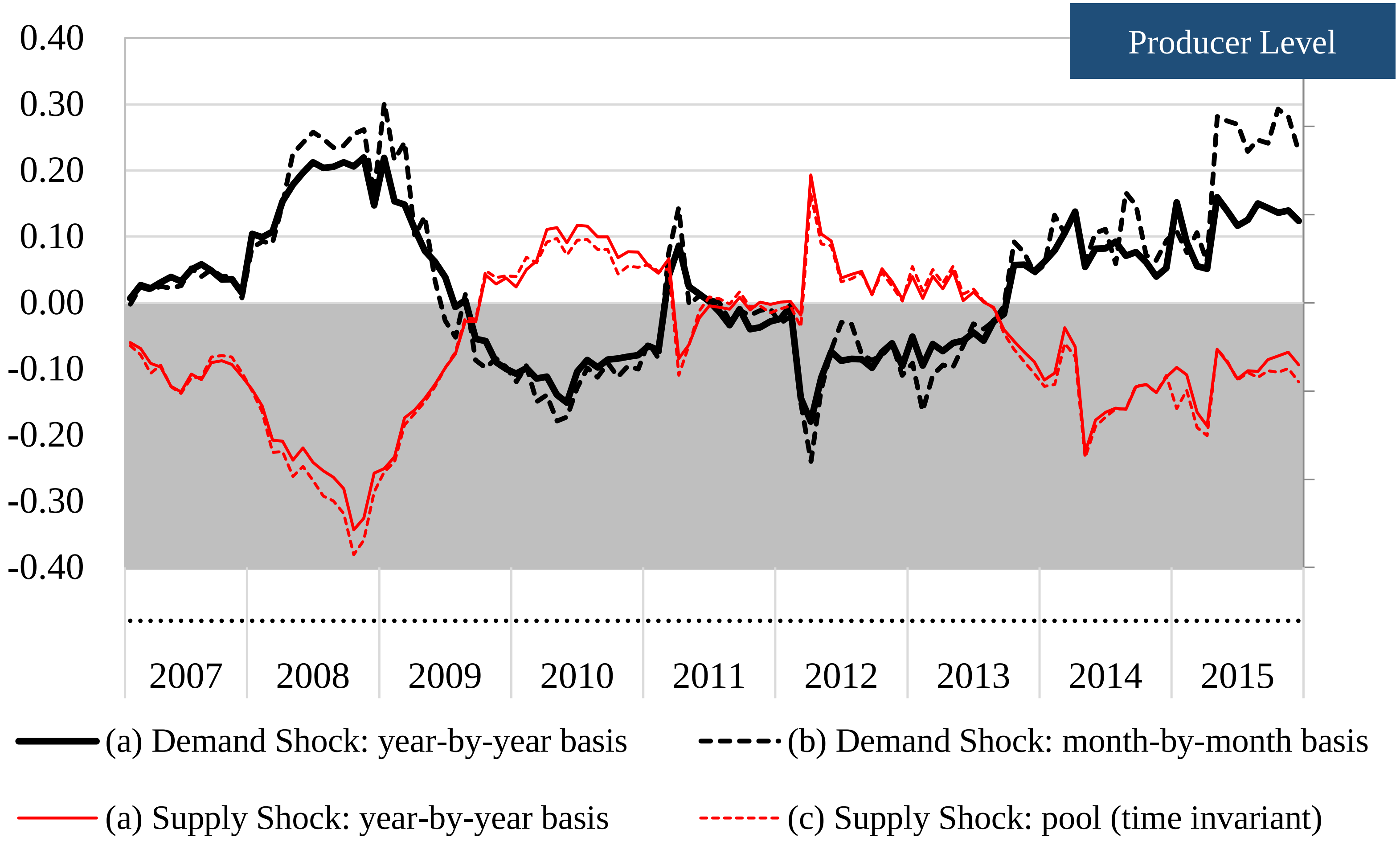
and repeat ② to find the initial value that minimizes the squared sum of residuals.

Figure 10: Changes in Estimates of Demand Elasticities



Note: 1) These estimates are for 336 categories, which have signs consistent with the model for σ and ω 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



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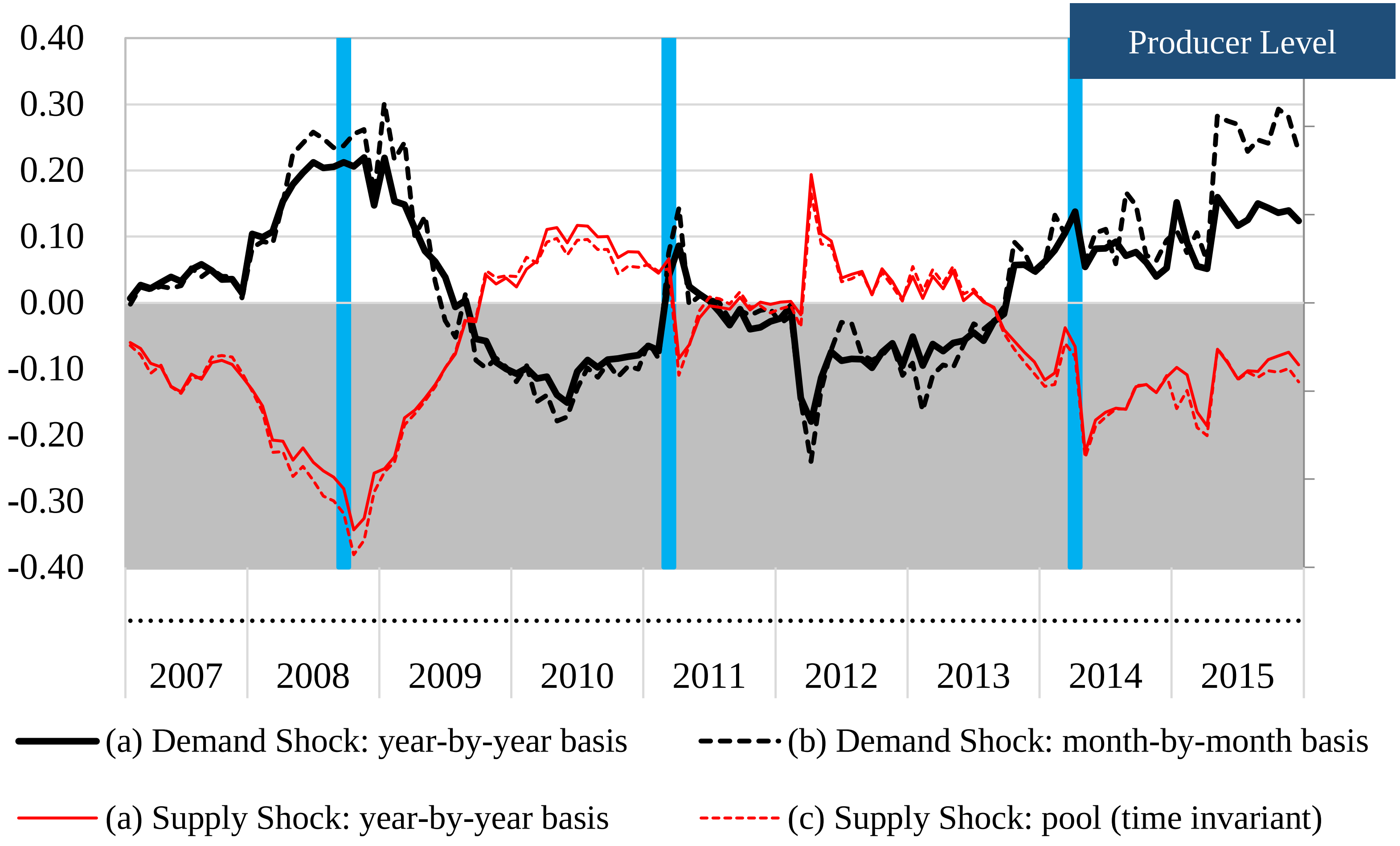


Note: These estimates are for 336 categories, which have signs consistent with the model for σ and ω and which pass the overidentification restrictions.

Comparisons with Traditional Methods of Estimating AS-AD Shocks

Traditional AD-AS Shocks

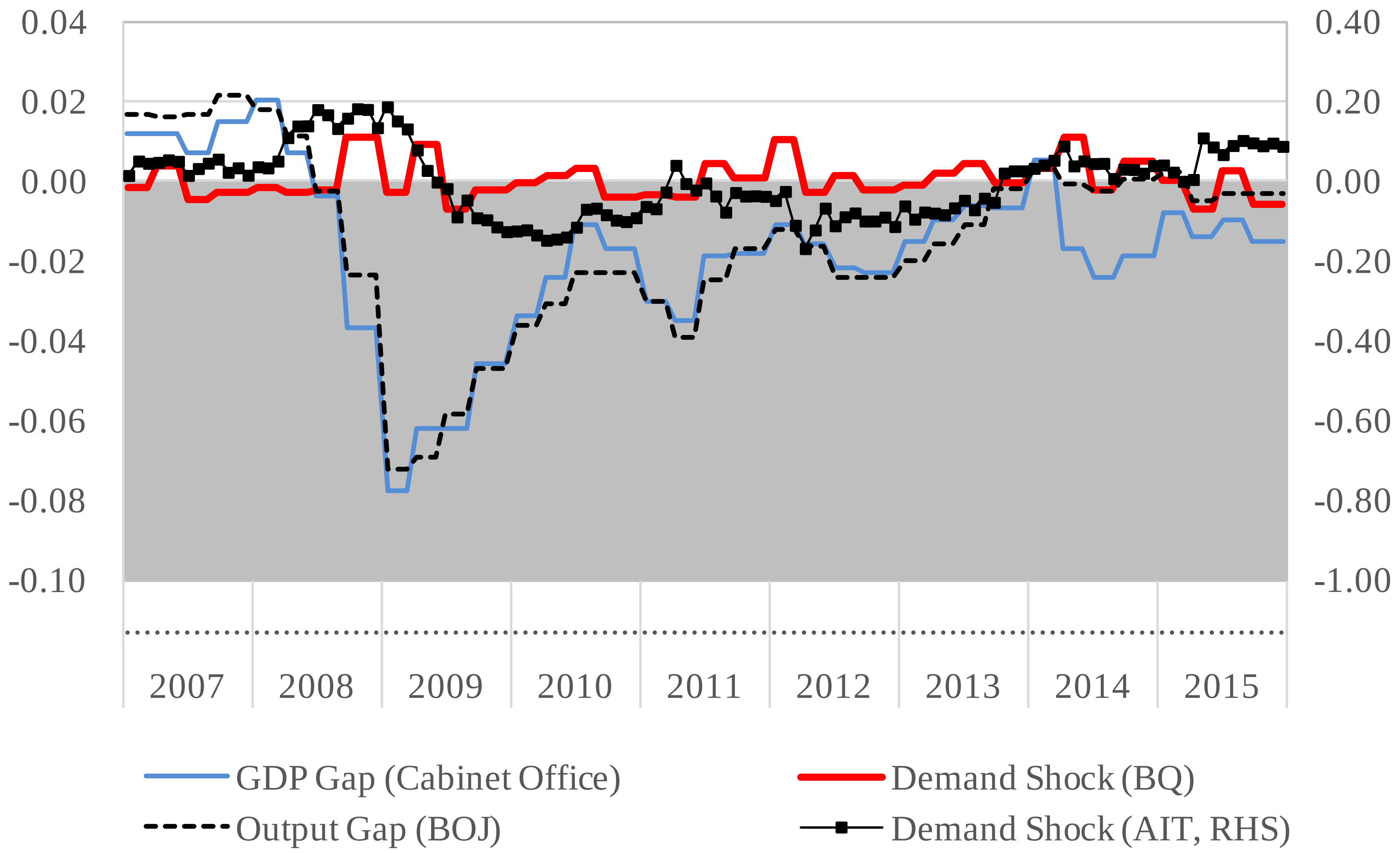
- Blanchard and Quah (1989): Long run restriction.

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

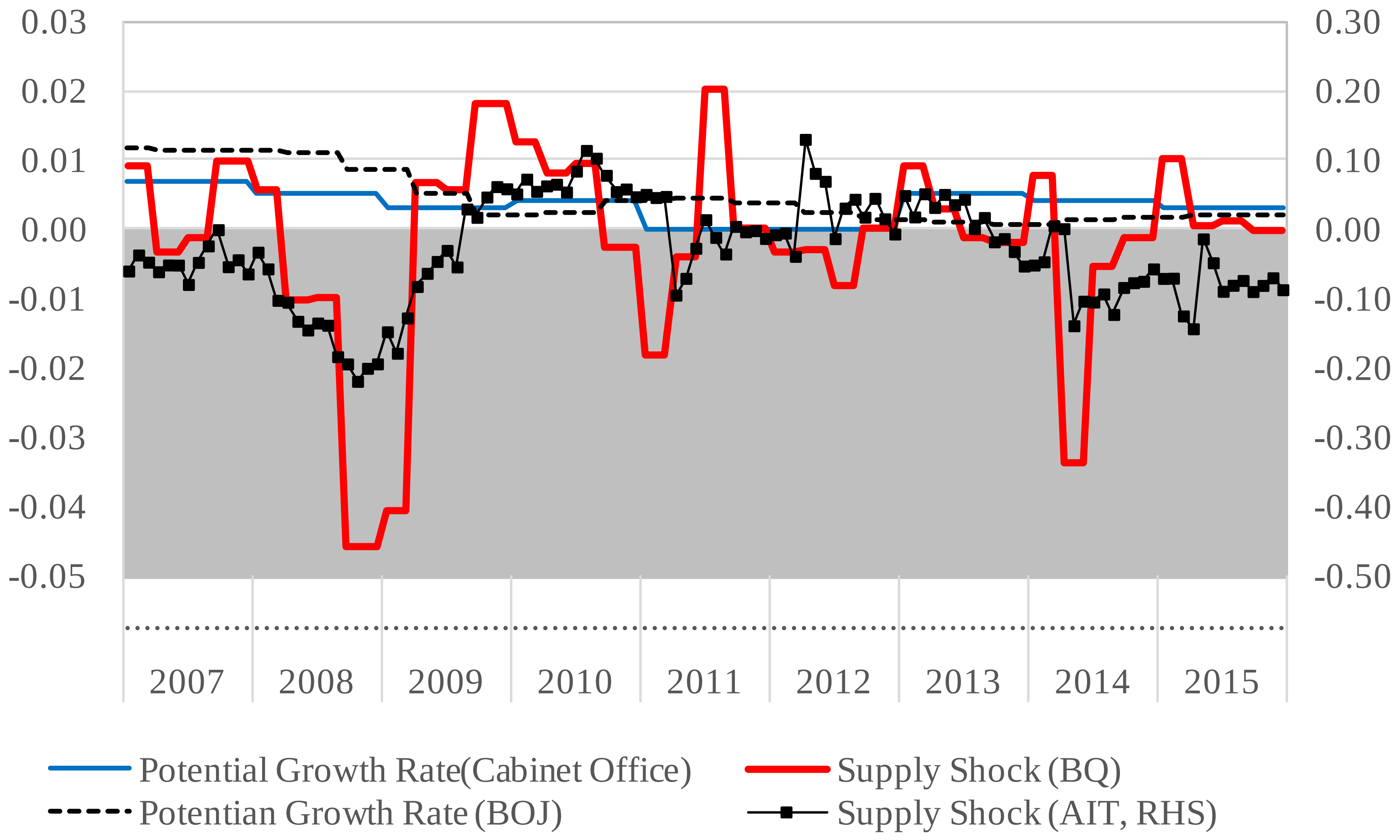
- GDP gap: Estimating potential GDP and taking the difference between the actual GDP and the potential GDP (Cabinet Office) or calculating the utilization rate of production factors (BOJ)

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

Demand Shock: Blanchard-Quah (BQ) and AIT

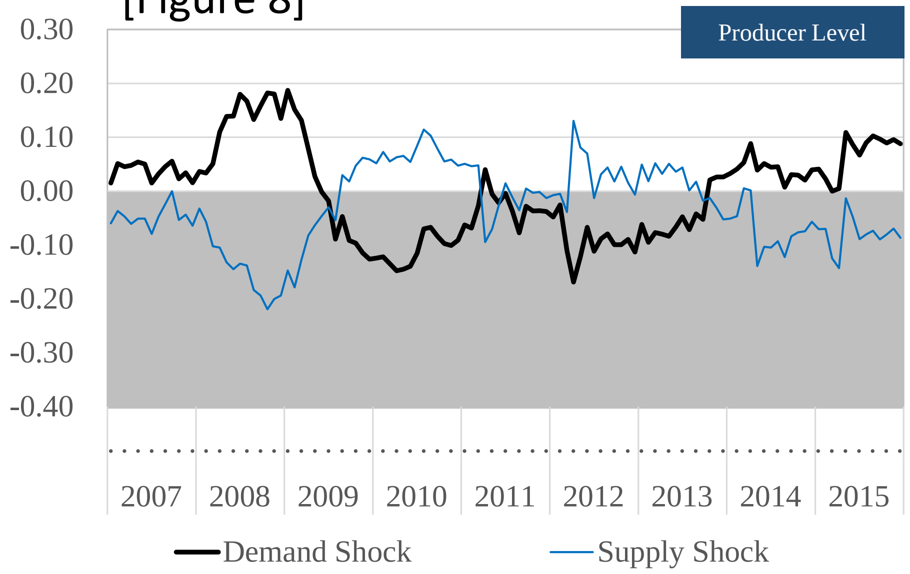


Supply Shock: Blanchard-Quah (BQ) and AIT



Major Findings

[Figure 8]



	Aggregate Demand Shocks	Aggregate Supply Shocks
2007	positive	negative
2008	positive large	negative large
2009-2010	negative	positive
The Great East Japan Disaster	temporal positive	temporal negative
2011-2013	negative	positive
Before the increase in Tax	positive	zero
late 2013-present	positive	negative

Recent Macroeconomic Events

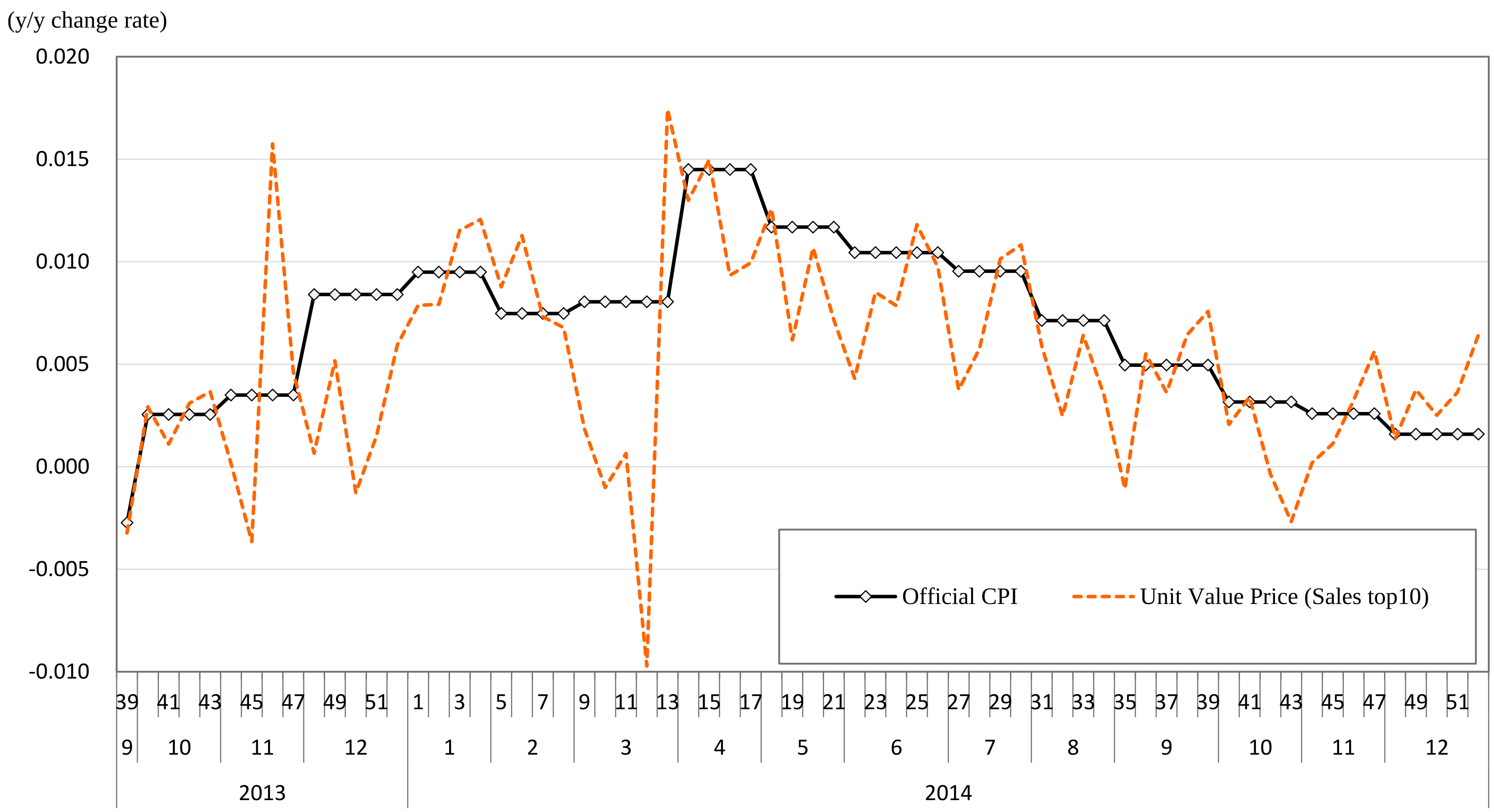
- In this framework, the change in consumption tax rate does not change the relative prices within category or stores.
- It does have an effect through changes in real income, Ct.
- Demand Elasticities are rising, but do not have significant effects on our estimates of AD and AS shocks.
- The inward 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

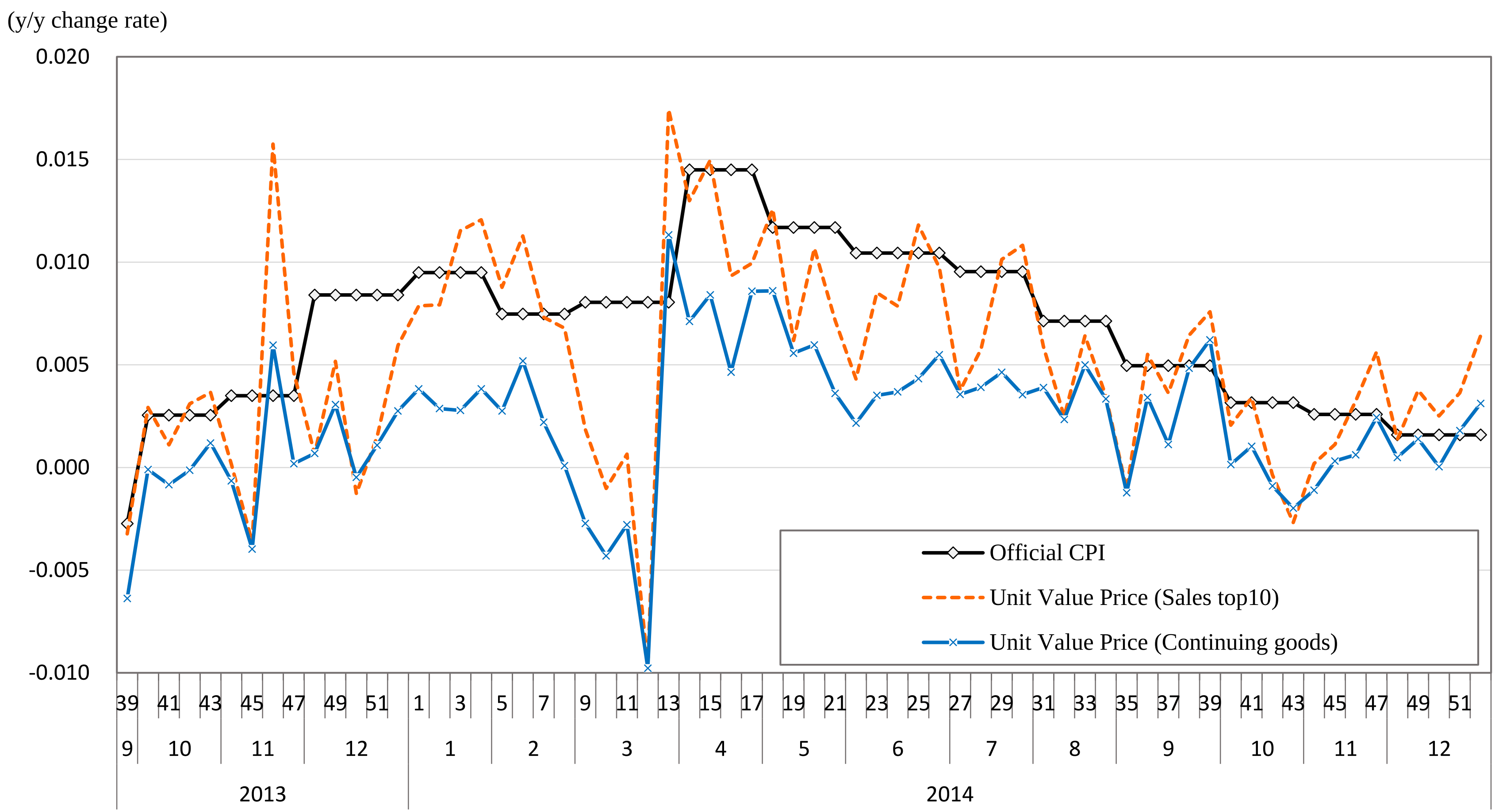
- Causes of the shocks (exchange rate, oil-material prices, wage, import and export, subsidy, etc.)
- Utilizing category specific, area specific information
- More detailed comparisons with the traditional approach
- If possible, relaxing assumptions of CES (Is AIDS possible?)

Comparisons with Official CPI

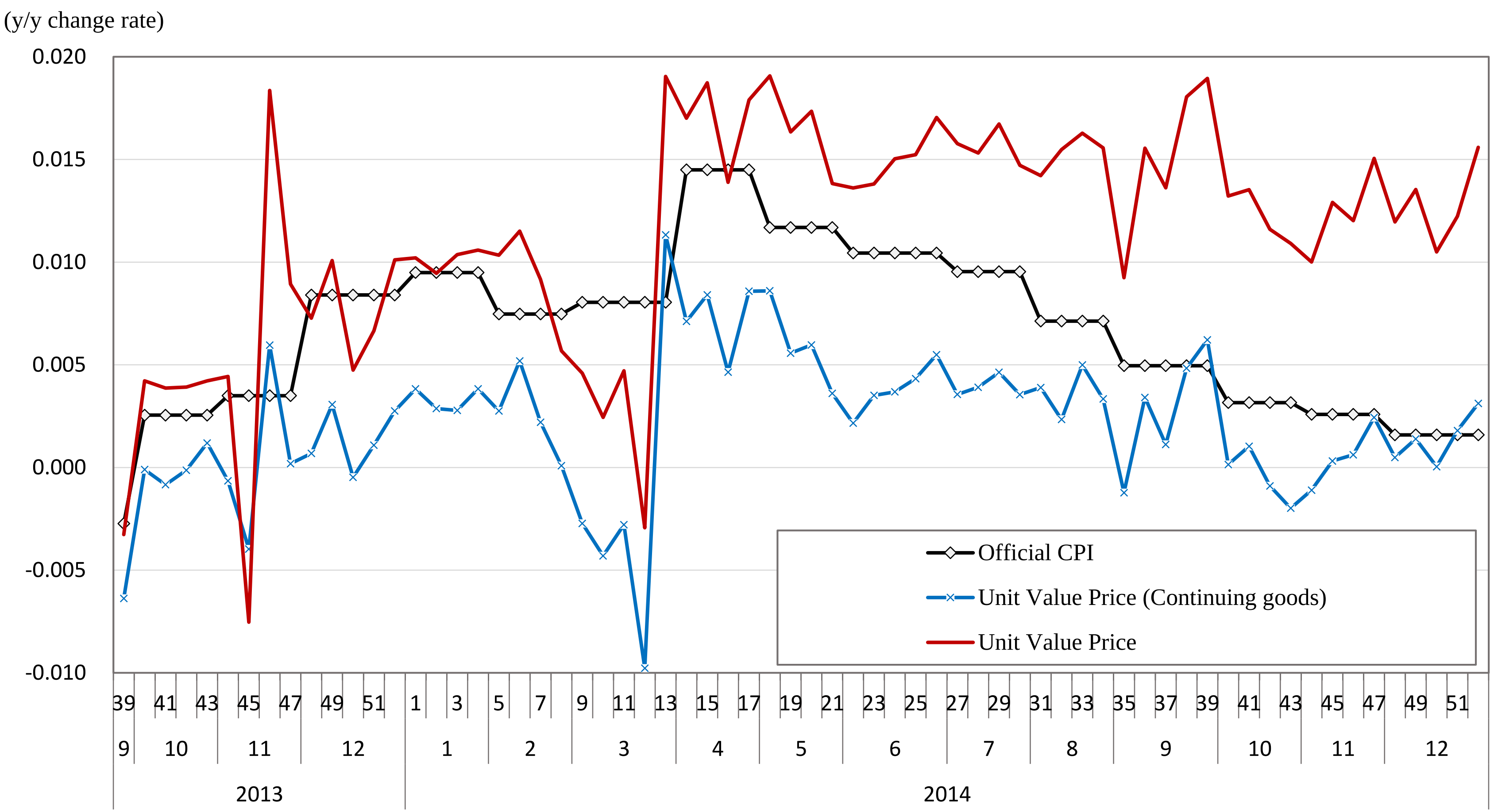
Official CPI and UVP with top 10



Official CPI and UVP with all the continuing goods



Official CPI and UVP including new goods



Official CPI and UVPs