# Testing the Stickiness of Macroeconomic Indicators and Disaggregated Prices in Japan: A FAVAR Approach

Tao Gu<sup>1</sup>

<sup>1</sup> Faculty of Economics, Meikai University, Japan

Correspondence: Tao Gu, Faculty of Economics, Meikai University, 1 Akemi, Urayasu, Chiba, 279-8550, Japan. Tel: 81-47-355-5120. E-mail: tgu@meikai.ac.jp

Received: April 5, 2014	Accepted: May 1, 2014	Online Published: June 25, 2014
doi:10.5539/ijef.v6n7p85	URL: http://dx.doi.org/10.5539/ijef.ve	6n7p85

# Abstract

This paper compares the stickiness of macroeconomic indicators and disaggregated prices in Japan using a factor-augmented vector autoregressive (FAVAR) approach. We present three main findings. First, fluctuations in common components are the main source of the volatility in disaggregated inflation rates, and generate most of the fluctuations in aggregate inflation. Second, disaggregated prices appear sticky in response to macroeconomic disturbances, but flexible in response to sector-specific shocks. Third, unexpected tight monetary policy shocks have a gradual negative effect on producer prices; however, only a minor effect was observed on consumer prices.

Keywords: sticky prices, monetary policy, macroeconomic models, VAR models

# 1. Introduction

Nominal price rigidities and monopolistic competition are the two core assumptions in New Keynesian models. In the absence of a commitment device or reputational considerations, these assumptions generate a time-consistency problem for monetary policy (Kydland & Prescott, 1977; Barro & Gordon, 1983). Therefore, the degree to which prices are sticky is a key parameter when evaluating the effects of monetary policy in the latest macroeconomic models.

Recently, evidence of the behavior of disaggregated prices suggests that prices are much more volatile than conventionally assumed in studies based on aggregate data, throwing suspicion on the hypothesis of price rigidity used in New Keynesian models. For instance, in the US case, Bils and Klenow (2004), examining the frequency of price changes for 350 categories of goods and services covering about 70% of consumer spending, based on unpublished data from the BLS for 1995 to 1997, report much more frequent price changes, with half of prices lasting 4.3 months or shorter. They conclude that actual inflation rates are far more volatile and transient than implied by the popular Calvo and Taylor versions of sticky-price models, thereby casting doubt on the validity of such models. In addition, Klenow and Kryvtsov (2008) report that price changes are frequent and typically large in absolute value using the CPI Research Database maintained by the US Bureau of Labor Statistics from 1988 to 2005. In the Japanese case, Abe and Tonogi (2010) use Japanese daily scanner data with three billion observations of prices and quantities from 1988 to 2005, investigating micro and macro price dynamics. They find that the frequency of price changes is much larger than that found in standard monthly datasets, casting doubt on standard New Keynesian assumptions.

However, Boivin et al. (2009) estimate a factor-augmented vector autoregression (FAVAR) model that augments the standard VAR with a small number of estimated factors summarizing large amounts of information about the economy, thus solving the degrees of freedom problem. This method can properly evaluate the relative importance of the sector-specific and macroeconomic shocks in the individual price series or macroeconomic price indices. The main finding of their study is that disaggregated prices appear sticky in response to macroeconomic and monetary disturbances, but flexible in response to sector-specific shocks, therefore suggesting that the flexibility of disaggregated prices is not in conflict with stickiness of aggregate inflation.

The purpose of this paper is to compare the stickiness of macroeconomic indicators and disaggregated prices in Japan using the FAVAR approach of Boivin et al. (2009). We find that fluctuations in the common factors are the main source of the volatility of disaggregated inflation rates, and generate most of the fluctuations in aggregate

inflation. Furthermore, disaggregated prices appear sticky in response to macroeconomic disturbances, but flexible in response to sector-specific shocks, implying the validity of the standard New Keynesian assumptions as discussed by Boivin et al. (2009). Third, we find that unexpected tight monetary policy shocks have a gradual negative effect on producer prices; however, only a minor effect was observed on consumer prices.

The remainder of the paper is organized as follows. Section 2 reviews the econometric framework of FAVAR, Section 3 discusses the various datasets used in our estimation, Section 4 presents the estimation results, and Section 5 concludes.

## 2. FAVAR Model

The empirical framework that we apply is based on the FAVAR model proposed in Bernanke et al. (2005). FAVAR augments the standard VAR with a small number of estimated factors summarizing large amounts of information about the economy and thus can solve the degrees of freedom problem, and reduces the chance of misspecifying the econometric model. In this paper, we follow the empirical strategy provided by Boivin et al. (2009) in which the FAVAR framework is used to decompose the volatilities of each variable into a common and an idiosyncratic component, and also macroeconomic disturbances, such as monetary policy shocks.

We explain the FAVAR framework developed by Bernanke et al. (2005) briefly below; please refer to the original paper for a full discussion. To analyze the effects of monetary policy, we assume that the collateralized overnight call rate,  $R_t$ , is the policy instrument. The rest of the common dynamics are captured by a  $K \times 1$  vector of important unobserved factors  $F_t$ , where K is relatively small. Assume that the joint dynamics of  $F_t$  and  $R_t$  are given by

$$\boldsymbol{C}_t = \boldsymbol{\Phi}(L)\boldsymbol{C}_{t-1} + \boldsymbol{v}_t \tag{1}$$

where  $C_t = \begin{bmatrix} F_t \\ R_t \end{bmatrix}$ , and  $\Phi(L)$  is a matrix of polynomials of finite order that may contain a priori restrictions, as in standard structural VARs. The error term  $v_t$  is i.i.d. with zero mean.

The system (1) is a VAR in  $C_t$ . We assume that the unobservable factors summarize the information contained in a large panel of economic time series. Let  $X_t$  be a  $N \times 1$  vector of a wide range of economic variables, where N is assumed to be large, i.e.,  $N \gg K + 1$ . Furthermore, we assume that the large set of observable series  $X_t$  is related to the common factors according to

$$\boldsymbol{X}_t = \boldsymbol{\Lambda} \boldsymbol{C}_t + \boldsymbol{e}_t \tag{2}$$

where  $\Lambda$  is an  $N \times (K+1)$  matrix of factor loadings, and the  $N \times 1$  vector  $e_t$  contains series-specific components that are uncorrelated with the common components  $C_t$ . These series-specific components are allowed to be serially correlated and weakly correlated across indicators. Following Boivin et al. (2009), we estimate this empirical model in two steps. In the first step, we extract principal components from the large dataset  $X_t$  to obtain consistent estimates of the common factors. In the second step, the FAVAR model is estimated by standard VAR methods with  $F_t$  replaced by  $\widehat{F_t}$ .

## 3. Datasets

The dataset used in the estimation of our FAVAR consists of 678 monthly series, and the data span the period from 1980:11 to 1998:8. (Note 1) In this paper, all data series are transformed using the first difference of the logs of series seasonally adjusted by Census X12 ARIMA software, except for interest rates, where the series are in levels, and the unemployment rate, which is only transformed using the first difference of the seasonally adjusted series.

Our dataset includes 134 monthly macroeconomic time series from the Nikkei NEEDS database. In the dataset, we appended 343 series of disaggregated consumer prices from the Ministry of Internal Affairs and Communications, and 201 series of disaggregated producer prices from the Bank of Japan. (Note 2) For brevity, we include the details of our data as well as the transformations applied to each particular series in an appendix, which is available from the author upon request.

## 4. Main Results

We used the two-step estimation system (1)–(2) for the FAVAR model using Matlab for the period 1980:11 to 1998:8, with the balanced panel data described in Section 3, and including five common factors in the vector  $F_t$ . The lag length used in estimating (1) is 13.

#### 4.1 Sources of Fluctuations and Persistence

We can analyze the sources of fluctuations in disaggregated (aggregated) inflation rates and the persistence in

disaggregated (aggregated) inflation rates by estimating the system (1)–(2). Some summary statistics of the volatility and the persistence of monthly inflation at both the macro and sectoral levels are reported in the following subsection.

## 4.1.1 Inflation Volatility

To investigate the sources of fluctuations in disaggregated inflation rates derived from (2), we use

$$\boldsymbol{\pi}_{it} = \boldsymbol{\lambda}_t' \boldsymbol{C}_t + \boldsymbol{e}_{it} \tag{3}$$

where  $\pi_{it}$  is the monthly log change in the respective price series, and  $\lambda_t$  is a vector of factor loadings. From this formulation, it is easy to decompose the fluctuations in disaggregated inflation rates due to the macroeconomic factors  $C_t$ , and sector-specific conditions represented by the term  $e_{it}$ .

As shown in the first column of Table 1, the standard deviation of monthly aggregate inflation for the consumer price index (CPI, without fresh food) is 0.20 percent, and ranges between 0.18 percent and 0.67 percent for the inflation rates of durable goods, nondurable goods, and services. The  $R^2$  statistic, which measures the fraction of the variance in inflation explained by the common component  $\lambda'_t C_t$ , lies above 0.5 for all of the aggregate measures except for nondurable goods, indicating that the main source of the volatility in aggregate inflation is shocks in common factors. However, the situation is considerably distinct for more disaggregated consumer prices and disaggregated producer prices. For example, the standard deviation is 1.38 percent on average (across sectors) for disaggregated inflation rates, which are more volatile than aggregate ones. In addition, the main source of this volatility is idiosyncratic shocks. As the empirical results shown in Table 1 show, the mean volatility of the common component of inflation is only 0.50 percent, whereas the idiosyncratic one is 1.26, more than twice as large. Furthermore, the average statistic for both disaggregated consumer prices and disaggregated producer prices is 0.26, implying that 74 percent of the fluctuations for the monthly disaggregated inflation are due to idiosyncratic shocks. We find a similar pattern for disaggregated consumer inflation rates and disaggregated producer inflation rates. Furthermore, the inflation volatilities are considerably different across sectors, and are dependent on sector-specific conditions. Table 1 shows that our results are close to those of Boivin et al. (2009).

#### 4.1.2 Inflation Persistence

Next, we discuss aggregate and disaggregated inflation persistence. To evaluate the extent of persistence, we also follow Boivin et al. (2009) by estimating for each inflation series  $\pi_{it}$  and each of its components,  $\lambda'_t C_t$  and  $e_{it}$ , an autoregressive process with 13 lags of the form

$$w_t = \rho(L)w_{t-1} + \varepsilon_t \tag{4}$$

and measuring the degree of persistence by the sum of the coefficients on all lags,  $\rho(1)$ .

As reported in Table 1, fluctuations in aggregate inflation are persistent with a  $\rho(1)$  value of 0.56 for the CPI (without fresh food) inflation rate, and range between 0.16 and 0.55 for the inflation rates of durable goods, nondurable goods, and services. On the other hand, the disaggregated inflation series exhibit different characteristics to the aggregated indicators. (Note 3) As illustrated in Table 1, the average level of persistence for all sectors is only 0.11, and varies significantly across sectors. In addition, the inflation persistence is attributable to fluctuations in common macroeconomic factors in most cases; however, the individual components exhibit, on average, nearly no persistence. These phenomena are also found in the US economy, as Boivin et al. (2009) noted.

Table 1.	Volatility	v and	persistence	of monthly	aggregated	and	disaggregated	inflation	series
		,							

		Standard deviation (in percent)				Persistence		
		Inflation	Common components	Sector specific	R2	Inflation	Common components	Sector specific
Aggregated serie	es							
CPI	All items, less fresh food	0.20	0.17	0.10	0.74	0.56	0.66	-0.63
	Durables	0.27	0.20	0.17	0.59	0.47	0.67	0.06
	Nondurables	0.67	0.43	0.51	0.41	0.16	0.64	0.29
	Services	0.18	0.13	0.11	0.58	0.55	0.66	-0.33
Disaggregated series ALL	Average	1.38	0.50	1.26	0.26	0.11	0.51	-0.03
	Median	0.62	0.28	0.54	0.22	0.19	0.58	0.01
	Min	0.13	0.06	0.09	0.00	-3.60	-0.33	-2.31
	Max	24.91	10.30	22.68	0.87	0.88	0.98	0.85

	Std	2.67	0.95	2.51	0.19	0.55	0.26	0.43
CPI	Average	1.55	0.53	1.43	0.27	0.10	0.54	0.00
	Median	0.56	0.27	0.49	0.23	0.24	0.58	0.02
	Min	0.13	0.06	0.09	0.00	-3.60	-0.17	-2.31
	Max	24.91	10.30	22.68	0.87	0.88	0.98	0.80
	Std	3.25	1.15	3.05	0.20	0.66	0.24	0.44
PPI	Average	1.08	0.45	0.97	0.25	0.13	0.46	-0.07
	Median	0.74	0.31	0.66	0.22	0.15	0.57	0.00
	Min	0.24	0.06	0.10	0.01	-1.04	-0.33	-1.35
	Max	7.15	2.83	6.74	0.86	0.73	0.82	0.85
	Std	1.06	0.41	1.00	0.18	0.27	0.28	0.40

*Note.* Sample is 1980:11–1998:8. Inflation is measured as the log difference of the price series *i*. Common components are  $\lambda'_t C_t$  and sector-specific components are  $e_{it}$  in (3), respectively.  $R^2$  statistics are the fraction of the variance of inflation explained by  $\lambda'_t C_t$ . Persistence is calculated using the estimated AR processes with 13 lags.

#### 4.2 Effects of Macroeconomic Shocks and Sector-Specific Shocks

In this subsection, we discuss the effects of sector-specific and macroeconomic shocks to the disaggregated price series. First, we confirm the response of each of the sectoral (log) price levels to its own sector-specific shock. As shown in the left panels of Figure 1A, sectoral price levels respond immediately after a reduction in  $e_{it}$  of one standard deviation, and tend to reach their new equilibrium level quickly (black solid lines display the (unweighted) average responses). Therefore, there is no persistence in the responses to the sector-specific disturbances for the disaggregated price series. Next, we examine the responses of prices to macroeconomic shock. The degree of the shock is a reduction in the common component  $\lambda'_t C_t$  by one standard deviation. In contrast to the responses to sector-specific disturbances, macroeconomic shocks produce relatively moderate price falls in the first few months after the shock, then reach their new equilibrium level in about 12 months on average. This is very different from the situation for sector-specific shocks, implying that the responses of prices to macroeconomic shocks are small, implying persistence in inflation rates.

Overall, the results above suggest that disaggregated prices appear sticky in response to macroeconomic disturbances, but flexible in response to sector-specific shocks.

#### 4.3 Impulse Response to Monetary Policy Shocks

To analyze the responses of the price series to monetary policy shocks, we consider an unexpected contractionary monetary policy shock, i.e., a 25-basis-point innovation in the collateralized overnight call rate. The results of the FAVAR estimation are presented in the right panels of Figure 1A. They contain the disaggregated price responses of CPI and PPI, the unweighted average responses (thick black solid line) of the disaggregated CPI and PPI, respectively, and the impulse responses of the aggregated CPI (without fresh food) and aggregated PPI (thick blue dashed line) to the same identified monetary policy shock. The unweighted average response of the CPI (without fresh food) shows a gradual increase; however, the response of the CPI (without fresh food) shows a minor decrease. In the PPI case, the unweighted average price response and the response of the aggregate price index to a monetary shock are very similar. They continue to decline after the monetary policy shock for nearly two years, and the size of the decline is greater than that of the CPI (without fresh food). Therefore, we conclude that the unexpected tight monetary policy shock has a gradual negative effect on producer prices; however, only a minor effect was observed on consumer prices.

Next, we examine the differences in the traditional VAR and the FAVAR frameworks. Figure 1B shows the result of a three-variable structural VAR model (PPI, IIP and Call Rate), (Note 4) the same VAR augmented with first principal component that summarize the information contained in a large number of economic variables and the FAVAR model. The thick blue solid line displays the impulse responses generated by the FAVAR, the thick green dashed line shows the impulse responses obtained from the three-variable structural VAR and the red solid line represents the responses of the same VAR augmented with one factor. Unlike the results of the estimation above, the PPI deflator is replaced by the CPI (without fresh food) in the structural VAR model. The impulse responses are displayed in Figure 1C. As illustrated, a "price puzzle" exists in the VAR models. Furthermore, the impulse response of IIP in the VAR is also inconsistent with standard economic theory. (Note 5) In contrast to the results estimated by structural VAR models, the FAVAR shows a more instinctive response of IIP, and more importantly, there is no positive response of the price index to the monetary policy tightening shock. The information set included in the FAVAR model is comparatively close to the information set of the actual monetary policy maker; therefore, this suggests that the FAVAR is more appropriate than the standard VAR approach.



Figure 1A. Sectoral price impulse responses to various shocks

*Note.* Estimated impulse responses of sectoral prices (in percent) to a sector-specific shock  $e_{it}$  of one standard deviation (left panels), to a shock to the common component  $\lambda'_t C_t$  of one standard deviation (middle panels), and to an identified monetary policy shock (right panels). The monetary shock is a surprise increase of 25 basis points in the collateralized overnight call rate. Thick black solid lines represent unweighted average responses. Thick blue dashed lines represent the response of the aggregate CPI (without fresh food) and PPI price indices to a monetary policy shock.



Figure 1B. Estimated impulse responses to an identified monetary policy shock (PPI)

*Note.* Sample is 1980:11–1998:8. Monetary shock is an unexpected increase of 25 basis points in the collateralized overnight call rate. Responses reported are estimated using the baseline FAVAR (thick blue solid line), the three-variable VAR (thick green dashed line), and the same VAR augmented with the first principal component of the large dataset (red solid line).



Figure 1C. Estimated impulse responses to an identified monetary policy shock (CPI, without fresh food) *Note.* See Figure 1B notes.



Figure 2A. Time series of the five factors before removing the consumption tax effect

*Note.* The five lines are extracted factors from the balanced panel dataset. The outliers in April 1989 and April 1997 indicate the consumption tax effects.



Figure 2B. Time series of the five factors after removing the consumption tax effect

*Note.* The five lines are extracted factors from the balanced panel data set after removing the consumption tax effect. We introduce dummy variables that equal 1 for the consumption tax months (April 1997 and April 1989) and 0 otherwise for the macroeconomic indicators and all disaggregated prices.

## 4.4 Controlling the Consumption Tax Effect

As a robustness check, we reestimate the model by controlling the consumption tax effect. The Japanese government imposed a consumption tax of 3% in April 1989 and raised it to 5% in April 1997. These events may affect the estimation results. To remove the consumption tax effect for the macroeconomic indicators and all disaggregated prices, we introduce dummy variables that equal 1 for consumption tax months (April 1997 and April 1989) and 0 otherwise (we do this using Stata). The differences in the time series of the five factors before and after removing the consumption tax effect are presented in Figures 2A and 2B, respectively. The estimated impulse responses of the sectoral price shocks are illustrated in Figure 3A. The cases of a sector-specific shock and a shock to the common component are similar to Figure 1A, supporting the robustness of our results. In Figures 3B and 3C, we again examine the differences in the three-variable structural VAR model, the same VAR augmented with one factor, and the FAVAR model. However, for the monetary policy shock, the results are counterintuitive, even in the FAVAR case. The reason for these phenomena may be that we did not consider all of the effects of the consumption tax, consumers may stock up on goods. Introducing dummy variables, such as the indicator of "Department Store Sales" in our database, that equal 1 for consumption tax months only, may not be adequate for removing this effect. This is a type of information loss that may affect the empirical results.



Figure 3A. Sectoral price impulse responses to various shocks after removing the consumption tax effect *Note.* The consumption tax effect of macroeconomic indicators and all disaggregated prices are removed. See also Figure 1A notes.



Figure 3B. Estimated impulse responses to an identified monetary policy shock after removing the consumption tax effect (PPI)

Note. The consumption tax effect of the macroeconomic indicators and all disaggregated prices are removed. See also Figure 1B notes.



Figure 3C. Estimated impulse responses to an identified monetary policy shock after removing the consumption tax effect (CPI, without fresh food)

Note. The consumption tax effect of the macroeconomic indicators and all disaggregated prices are removed. See also Figure 1B notes.

## 5. Conclusion

The purpose of this paper is to compare the stickiness of macroeconomic indicators and disaggregated prices in Japan using a FAVAR approach. There are three main findings. First, fluctuations in the common factors are the main source of volatility in disaggregated inflation rates and generate most of the fluctuations in aggregate inflation. Second, disaggregated prices appear sticky in response to macroeconomic disturbances, but flexible in response to sector-specific shocks, implying the validity of the standard New Keynesian assumption as discussed by Boivin et al. (2009). Third, unexpected tight monetary policy shocks have a gradual negative effect on producer prices; however, only a minor effect was observed on consumer prices. In future research, an estimation that considers the period of zero interest rate policy since 1999 in Japan is required. A Markov-switching dynamic factor model may be a suitable method for this exercise.

#### Acknowledgements

I would like to express my sincere gratitude to Etsuro Shioji, Tsutomu Watanabe, and an anonymous referee for their helpful comments and encouragement. This research is financially supported by the Suntory Foundation. Of course, all errors remain my responsibility.

## References

Abe, N., & Tonogi, A. (2010). Micro and Macro Price Dynamics in Daily Data. *Journal of Monetary Economics*, 57, 716–728. http://dx.doi.org/10.1016/j.jmoneco.2010.05.016

Altissimo, F., Mojon, B., & Zaffaroni, P. (2007). Fast Micro and Slow Macro: Can Aggregation Explain the

*Persistence of Inflation?* FRB of Chicago Working Paper No. 2007–02. http://dx.doi.org/10.2139/ssrn.967748

- Barro, R. J., & Gordon, D. B. (1983). A Positive Theory of Monetary Policy in a Natural Rate Model. *Journal of Political Economy*, 91, 589–610. http://dx.doi.org/10.1086/261167
- Bernanke, B. S., & Blinder, A. S. (1992). The Federal Funds Rate and the Channels of Monetary Transmission. *American Economic Review*, 82, 901–921.
- Bernanke, B. S., Blinder, & Eliasz, P. S. (2005). Measuring MonetaryPolicy: A Factor Augmented Vector Autoregressive (FAVAR) Approach. *Quarterly Journal of Economics*, 120, 387–422. http://dx.doi.org/10.1162/0033553053327452
- Bils, M., & Klenow, P. J. (2004). Some Evidence on the Importance of Sticky Prices. *Journal of Political Economy*, *112*, 947–985. http://dx.doi.org/10.1086/422559
- Boivin, J., Giannoni, M. P., & Mihov, I. (2009). Sticky Prices and Monetary Policy: Evidence from Disaggregated US Data. *American Economic Review*, 99, 350–384. http://dx.doi.org/10.1257/aer.99.1.350
- Clark, T. E. (2006). Disaggregate Evidence on the Persistence of Consumer Price Inflation. *Journal of Applied Econometrics*, 21, 563–587. http://dx.doi.org/10.1002/jae.859
- Klenow, P. J., & Kryvtsov, O. (2008). State-Dependent or Time-Dependent Pricing: Does It Matter for Recent U.S. Inflation? *Quarterly Journal of Economics*, 123, 863–904. http://dx.doi.org/10.1162/qjec.2008.123.3.863
- Kydland, F. E., & Prescott, E. C. (1977). Rules Rather than Discretion: The Inconsistency of Optimal Plans. *Journal of Political Economy*, 85, 473–491. http://dx.doi.org/10.1086/260580
- Shibamoto, M. (2007). An Analysis of Monetary Policy Shocks in Japan: a Factor Augmented Vector Autoregressive Approach. *Japanese Economic Review*, 58, 484–503. http://dx.doi.org/10.1111/j.1468–5876.2007.00392.x
- Sims, C. A. (1992). Interpreting the Macroeconomic Time Series Facts: The Effects of Monetary Policy. *European Economic Review*, 36, 975–1000. http://dx.doi.org/10.1016/0014-2921(92)90041-T

### Notes

Note 1. We choose this period to avoid the effects of the second oil price shock and the zero interest rate monetary policy regime.

Note 2. Disaggregated producer prices are available from 1980:1. In this paper, we normalized them to the base year of 2005 following a suggestion made by the Bank of Japan.

Note 3. See also Clark (2006) and Altissimo et al. (2007).

Note 4. IIP is the abbreviation for Index of Industrial Production (Mining and Manufacturing).

Note 5. Shibamono (2007) obtains the same result for Japan.

## Copyrights

Copyright for this article is retained by the author(s), with first publication rights granted to the journal.

This is an open-access article distributed under the terms and conditions of the Creative Commons Attribution license (http://creativecommons.org/licenses/by/3.0/).