The Impact of Postponing Announced Unconventional Fiscal Policy on Consumption Expenditure

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Abstract

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keywords: Fiscal policy; VARX; Japan; VAT

JEL classification: C31, C50, E20, E31, E62, E65

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1 Introduction

Governments across the world struggle to stimulate economies without causing a heavy budget dificit. Large stocks of sovereign debt pushed by welfare states limit the scope of fiscal stimulus, whereas the zero lower bound on nominal interest rates and inflated central bank balance sheets constrain the use of conventional and unconventional monetary policy. Eggertsson and Woodford (2006) have recently proposed unconventional fiscal policy measures to stimulate demand by changing intertemporal prices. An unconventional fiscal policy uses announcements of future increases in consumption taxes to generate inflation expectations and accelerate consumption expenditure. It differs from the conventional fiscal stimulus or tax rebates because it offer government an option to revise the policy later. It stimulates consumption and helps government to compensate for a large budget dificit.

In a recent natural experiment in Japan, the VAT policy sequence displays significant time inconsistency resutled from political instability. Due to the significant fiscal burden left by the last government together with the aging of Japanese society, in June 2012 (2012Q2), the lower house of Japan passed the bill of Noda government to raise the consumption tax to 8% in April 2014 (2014 Q2) and to 10% in October 2015 (2015 Q4). This policy causes social anger and fails the Noda government in the next election. In November 2014 (2014 Q4), to win public support, the Abe government decided to delay the tax increase to 10% till April 2017 (2017 Q2). In May 2016 (2016 Q2), a second postponement was announced by Abe government, which further delayed the increase to October 2019.

The time series plots of Private Final Consumption Expenditure of Japan in Figure 1 and the Growth Rate of Consumer Price Index (All Items Non-Food and Non-Energy for Japan) in Figure 2 show significant variation in both indicies between 2008 and 2016.

The fluctuation started to be significant from 2008 because of the worldwide economic recession. The salient fluctuation around 2014 (an increase followed by a sharp

Figure 1: Private Final Consumption Expenditure in Japan
Trillions of Japanese Yen, Seasonally Adjusted

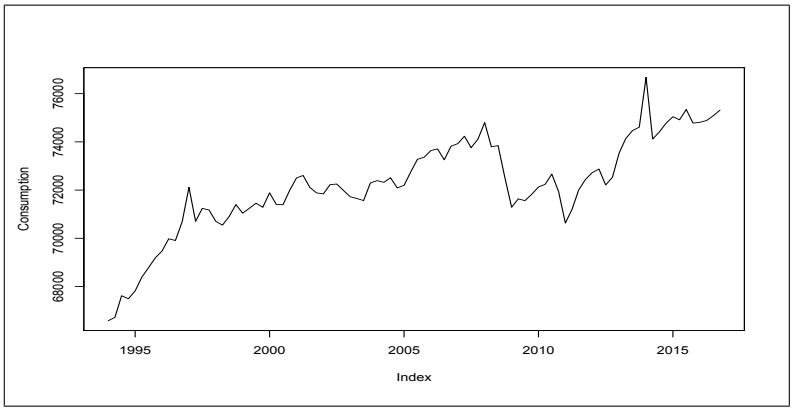
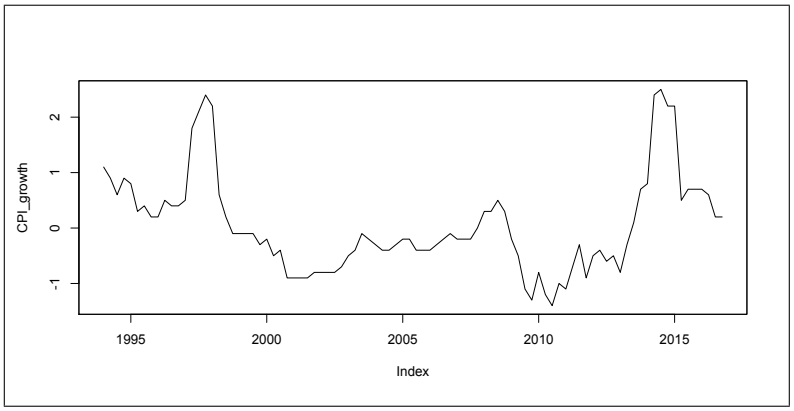


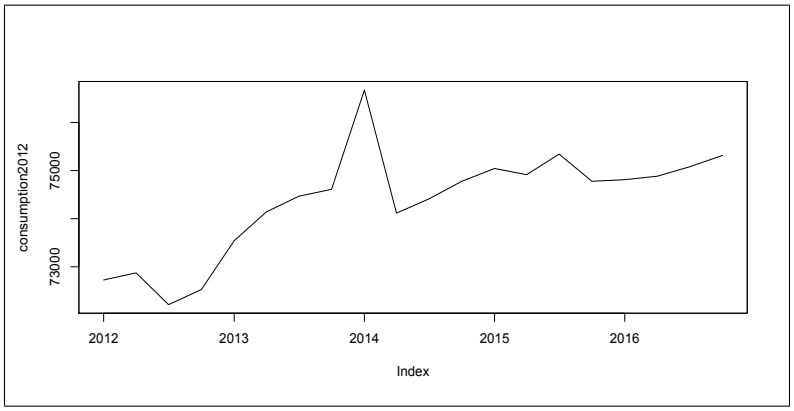
Figure 2: Growth Rate of Consumer Price Index(All Items Non-Food and Non-Energy for Japan)
Same Period Previous Year,Not Seasonally Adjusted



decrease) came from the Japanese consumption tax policy. By a closer look at Figure 1 in the period between 2012 and 2016, an increase trend can be readily seen from 2012 Q3, soon after the announcement of VAT increase, to 2014 Q1, shortly before the first exercise date. The most drastic increase appeared in 2014 Q1, just before the exercise date. In 2014 Q2, the first decrease appeared accompanied by the first announcement of the policy sequence. The decrease was sharp but ended immediatly. However, the consumption didn't go back to the same level until the first postponment was announced.

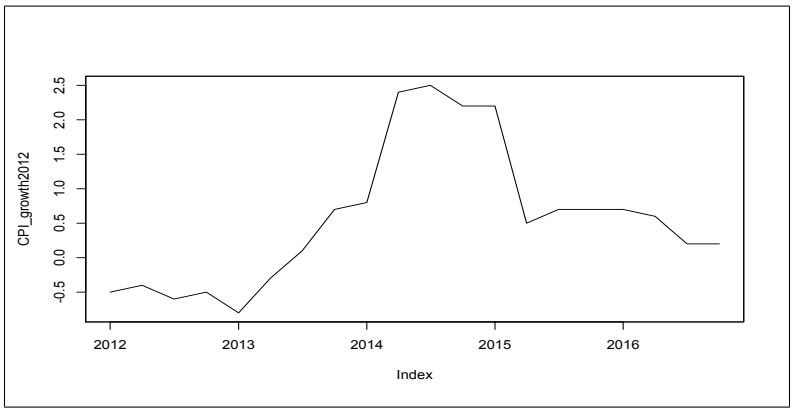
The Growth rate of CPI responded to the policy sluggishly and relative persistently, which suggests a lag in CPI with the policy. However, the overall trend of CPI

Figure 3: Private Final Consumption Expenditure since 2012
Trillions of Japanese Yen, Seasonally Adjusted



growth rate is similar to that of consumption.

Figure 4: Growth Rate of Consumer Price since 2012
Same Period Previous Year,Not Seasonally Adjusted



In this paper, we study the reaction and expectation of consumers when government announces a future sales tax increase but has the option to postpone it. The empirical test for the effect of the VAT policy sequence on consumption expenditure and the inflation rate is conducted through Vector Auto-regression Model (VAR). The empirical test for the short term postponing effect of unconventional fiscal policy, which wasn't predicted by the households, is conducted through Vector Auto-regression Model with Exogenous Variables (VARX). And lags of the exogenous variables are set to be zero. The empirical test for the short term postponing effect of unconventional fiscal policy, which was partially predicted by the households, is

conducted through Vector Auto-regression Model with Exogenous Variables (VARX). And lags of the exogenous variables are set to be non-zero For each model, we prdefict the treatment effect of the VAT policy and the postponement.

Through the empirical tests mentioned above, we find that the treatment effect of the whole unconventional fiscal policy sequence is not idea. The pre-annoucement of tax increases generate high consumption in the short time, but after the first exercise day, consumption drops shaply and haven't recovered to the same level if the policy were not conducted. This phenomenon may raise from the fact that unconventional fiscal policy squeezed the future consumption to the short term. After the households cornered large amount to durable goods such as household applience, cars etc., they have no incentive to buy more. The replacement period of durable goods are long, thus even when they expected another tax increase in the near future, they have no incentive to store more.

We also find that the treatment effect of postponement is idea. The postponements of the second unconventional fiscal policy actually dragged consumption to a higher level than if the policy were not postponed. This phenomenon may raise from the fact that if the policy were not postponed, the whole VAT policy sequence may already ternimated in November 2015. Houslds might finish their shopping lists of durable goods and have no plan to buy no ones in the next several years. Thus, in our prediction period, households have no incentive to spend much and the predicted consumption remains a low lever. Thus, in this sense, postponements on the second tax increase gernerates persistent policy sequences and persistent inflation expectation. Thus the unexpected postponement have positive effects on Janpanese economy.

2 Literature Review

The existing research related to my topic can be divided into two categories. One is on the effect of unconventional fiscal policy, the other is on the time consistency and optimal policy design.

Through a Ramsey taxation model, Feldstein (2002) argues that value-added tax

(VAT) induced by inflation would incentivize households to spend sooner rather than waiting until prices become substantialy higher later. Hall (2011) claims that pre-announced increases in VAT generate inflation of consumer price and stimulate spending via intertemporal substitution. Correia, Farhi, Nicolini and Teles (2013) formalize these ideas in a theoretical framework with a binding zero lower bound on nominal interest rates. An increasing path of consumption taxes and a decreasing path of income taxes lead to inflation expectations, negative real interest rates, and thus stimulates consumption but does not distort production decisions. Through the natural experiment in Germany(2005-2007), DAcunto, Hoang and Weber (2015) and DAcunto, Hoang and Weber (2016) find that households who expect an increase in inflation have a 8% higher reported readiness to spend on durables compared to other households. They find that the unconventional fiscal policy is successful in stimulating consumption expenditure.

Unconventional fiscal policies have another advantage. Eggertsson and Woodford (2004), Eggertsson and Woodford (2006), Correia et al. (2013), DAcunto et al. (2016) show that uncoventional fiscal policy is time consistent at zero bound. In other words, even if the planner were given an opportunity to revise the unvonventional fiscal policy in the future, he would choose not to.

The time consistency of unconventional fiscal policy, however, is only valid when the political turnover of the government is ignored. Policymakers are assumed to be myopic and are concerned with the outcome in their own tenure period. Under the loose commitment of policymakers, Debortoli and Nunes (2010) show that the autocorelation of taxes is low. Like fiscal simulas, unconventinal fiscal policy is made by a benevolent government and is periodically revised.

This paper contributes to the literature in that it studies the unconventional fiscal policy under loose commitment. First, past literatures on unconventional fiscal policy only measure the effect of policies themselves and deny the existence of time inconsistency in the policies while this paper also measures the postponing effect of unconventional fiscal policy. Second, paster literatures on time inconsistency of fiscal policy only analyze the capital income tax while this paper extends the time

inconsistency concept to the unconventional value-add-tax.

3 Model

When there is no unconventional fiscal policy, Galí (2015) proposes a standard New Keynesian model where the preferences of a representative household is described over aggregate consumption C_t and leisure L_t.

$$E_0 \sum_{t=0}^{\infty} \beta^t u(C_t, L_t) \tag{1}$$

When there exists unconventional fiscal policy, Correia et al. (2013) introduces a preference shock ξ_t into utility function of representative household to characterize the policy:

$$E_0 \sum_{t=0}^{\infty} \beta^t u(C_t, L_t, \xi_t) \tag{2}$$

$$u(C_t, L_t, \xi_t) = u(C_t, L_t)\xi_t \tag{3}$$

In this way, the preference shock does not affect the marginal rate of substitution between consumption and leisure. It does, however, affect the marginal rate of substitution between consumption at time t and time $t+1$. Correia et al. (2013) thus suggest an equilibrium for $\{C_t, N_t, K_t, P_t, W_t\}$, where W_t is nominal wage.

Correia et al. (2013) assume that ξ_t evolves exogenously according to $\xi_t/\xi_{t+1} < \beta$ for $t = 0, 1, ..., T-1$, and $\xi_t/\xi_{t+1} = 1$ for $t \geq T$, where T is the exercise day of the unconventional fiscal policy. In this way, they exclude the possibility of any revision on the announced unconventional fiscal policy.

However, revison of unconventional fiscal policy will not only change the size, but also will affect the duration of policy treatment. In order to capture the postponing effect of unconventional fiscal policy, we loose the assumption that ξ_t evolves exogenously and model the postponement as a shock on preference shock.

Hence, when there is no unconventional fiscal policy, the economy can be char-

icterized by Vector Auto-regression Model (VAR) as following:

$$\begin{bmatrix} C_t \\ K_t \\ N_t \\ P_t \\ W_t \end{bmatrix} = \phi_0 + \sum_{i=1}^{p} \phi_i \begin{bmatrix} C_{t-i} \\ K_{t-i} \\ N_{t-i} \\ P_{t-i} \\ W_{t-i} \end{bmatrix} + a_t \tag{4}$$

where p is the lag of time series $\{C_t, K_t, N_t, P_t, W_t\}$, ϕ_0 is a 5-dimentional constant vector, ϕ_i are 5×5 real-valued matrices, $\{at\}$ is a sequence of serially uncorrelated random vectors with mean zero and positive-definite covariance matrix $\sum_a$.

When the revison of unconventional fiscal wasnt expected by the household, consumers make decision based on the present information. They adjust their expectation of tax rate and exercise date of the policy periodically. And their expectaion won't affect the expectation of next period. In other words, the expectation of tax rate and exercise date of the policy have no lags. Thus, the economy can be charicterized by Vector Auto-regression Model with exogenous variables (VARX) as following:

$$\begin{bmatrix} C_t \\ K_t \\ N_t \\ P_t \\ W_t \end{bmatrix} = \phi_0 + \sum_{i=1}^{p} \phi_i \begin{bmatrix} C_{t-i} \\ K_{t-i} \\ N_{t-i} \\ P_{t-i} \\ W_{t-i} \end{bmatrix} + B \begin{bmatrix} E[\Delta\tau]_t \\ E[T-t]_t \end{bmatrix} + a_t \tag{5}$$

where $\Delta\tau$ is the change of VAT rate, B is 5×2 coefficient matrix.

When the revison of unconventional fiscal was expected by the household, consumers make decision not only based on the present information, but also on the historical ones. Although their expectaion won't affect the expectation of next period, it will consistently toture householes' consumption decision. In other words, their expectation have lags on time series $\{C_t, K_t, N_t, P_t, W_t\}$. Thus, the economy can be charicterized by Vector Auto-regression Model with exogenous variables (VARX) as

following:

$$\begin{bmatrix} C_t \\ K_t \\ N_t \\ P_t \\ W_t \end{bmatrix} = \phi_0 + \sum_{i=1}^{p} \phi_i \begin{bmatrix} C_{t-i} \\ K_{t-i} \\ N_{t-i} \\ P_{t-i} \\ W_{t-i} \end{bmatrix} + \sum_{j=1}^{s} B_i \begin{bmatrix} E[\Delta\tau]_t \\ E[T-t]_t \end{bmatrix} + a_t \tag{6}$$

where $\Delta\tau$ is the change of VAT rate, B_j are 5×2 coefficient matrices.

In order to evaluate the policy treatment effect and postponing effect, we conduct predictions through the constructed models and measure the difference between predicted real world values.

4 Data

Data sources of this paper are Federal Reserve Bank(2016 OECD) and Penn World Table 9.0. The policy announcement/exercise date and the rate of tax increase can be found from Wikipedia and can be verified through Ministry of Finance, JAPAN; The House of Representatives, Japan; and Ministry of Internal Affairs and Communication.

The empirical analysis is conducted using Japanese quarterly time series data from 1994Q1 to 2016Q4. The endogenous variables($\{C_t, K_t, N_t, P_t, W_t\}$) are constructed using the seasonally adjusted index data (2010=1) of each time series. Consumption Index of Japan is calculated from Private Final Consumption Expenditure in Japan and Consumer Price Index(CPI) for Japan; Since $\{C_t, N_t, P_t, W_t\}$ are flow concepts while $\{K_t\}$ is stock concept, we use Gross Domestic Product by Expenditure in Constant Prices: Gross Fixed Capital Formation for Japan ($\{Kf_t\}$) to substitute $\{K_t\}$; Price Index(P_t) of Japan is represented by Consumer Price Index: Total All Items for Japan (CPI_t); Labor supply index(N_t) is represented by Monthly Hours Worked: Manufacturing for Japan; Nominal Wage(W_t)is represented by Hourly Earnings: Manufacturing for Japan; Those time serieses can be found directly from FRED.

Assume when there are two unconventional fiscal policies at the same time, short-

sighted households only care about the most recent one. The exogenous variables ($\{E[\Delta\tau]_t E[T-t]_t\}$) are constructed from Japanese VAT policy sequence since June 2012, the first annoucement of unconventional fiscal policy in Japan, as in Table 1.

Table 1: The Expectation of Households on Future VAT Rate Increase and Remaining Duration before the Exercise Date

Date t	Exercise Date $E[T]$	$E[T-t]_t$(in Months)	$E[T-t]_t$(in Years)	Expected Tax Rate Change
2012 Q3(July)	April 2014	21	1.75	3%
2012 Q4(October)	April 2014	18	1.5	3%
2013 Q1(January)	April 2014	15	1.25	3%
2013 Q2(April)	April 2014	12	1	3%
2013 Q3(July)	April 2014	9	0.75	3%
2013 Q4(October)	April 2014	6	0.5	3%
2014 Q1(January)	April 2014	3	0.25	3%
2014 Q2(April)	October 2015	18	1.5	2%
2014 Q3(July)	October 2015	15	1.25	2%
2014 Q4(October)	October 2015	12	1	2%
2015 Q1(January)	April 2017	27	2.25	2%
2015 Q2(April)	April 2017	24	2	2%
2015 Q3(July)	April 2017	21	1.75	2%
2015 Q4(October)	April 2017	18	1.5	2%
2016 Q1(January)	April 2017	15	1.25	2%
2015 Q2(April)	April 2017	12	1	2%
2015 Q3(July)	October 2019	39	3.25	2%
2015 Q4(October)	October 2019	36	3	2%

When perform regression, we use Expected Policy Duration before Exercise Date in Years.

5 Estimation

Before establish model and perform model checking, we first take a close look at the multivariate time serieses $\{C_t, Kf_t, N_t, CPI_t, W_t\}$ as in Figure 5.

The acf(Figure 6) and pacf(Figure 7) plots of the multivariate time serieses $\{C_t, Kf_t, N_t, CPI_t, W_t\}$ suggest there are lags in the time serieses.

Figure 5: Plots of Multivariate Time Serieses $\{C_t, Kf_t, N_t, P_t, W_t\}$
Index 2010=1, Seasonally Adjusted

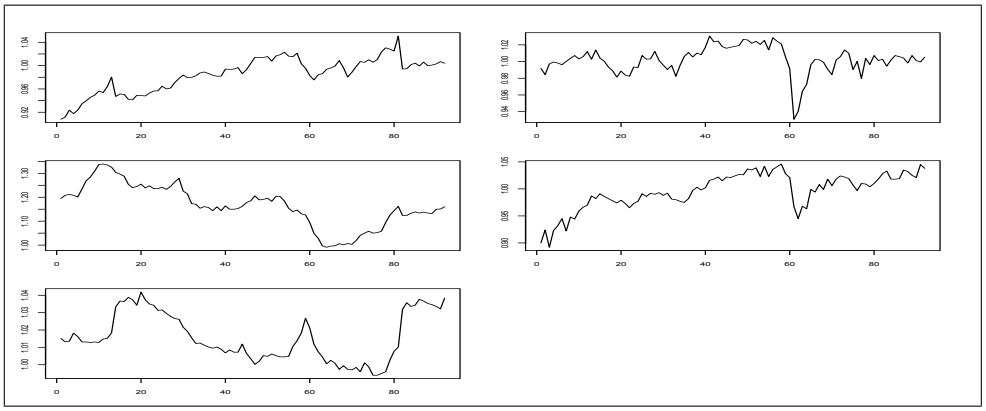
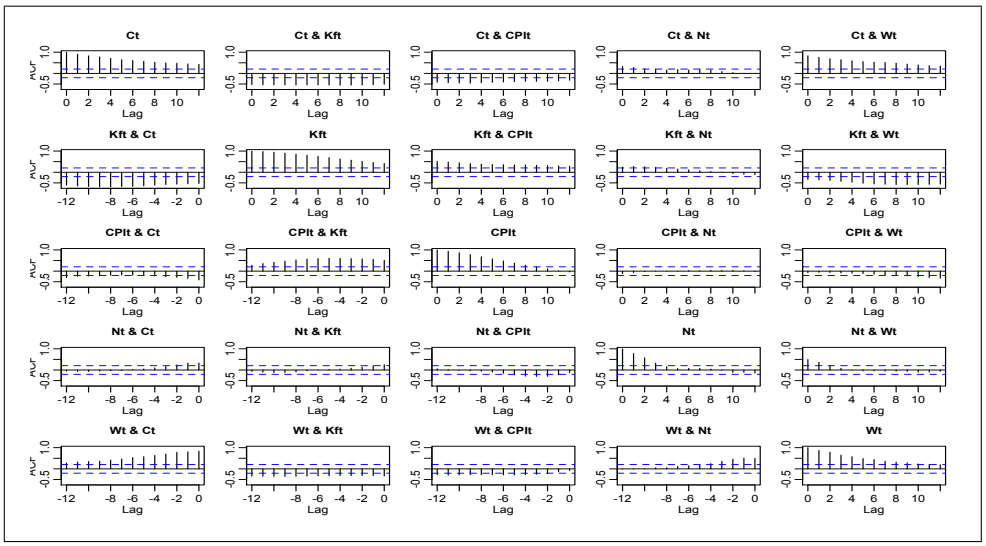


Figure 6: Acf Plots of $\{C_t, Kf_t, N_t, P_t, W_t\}$



Next, we'll apply these multivariate time serieses data into the VAR and VARX models stated in Section 3.

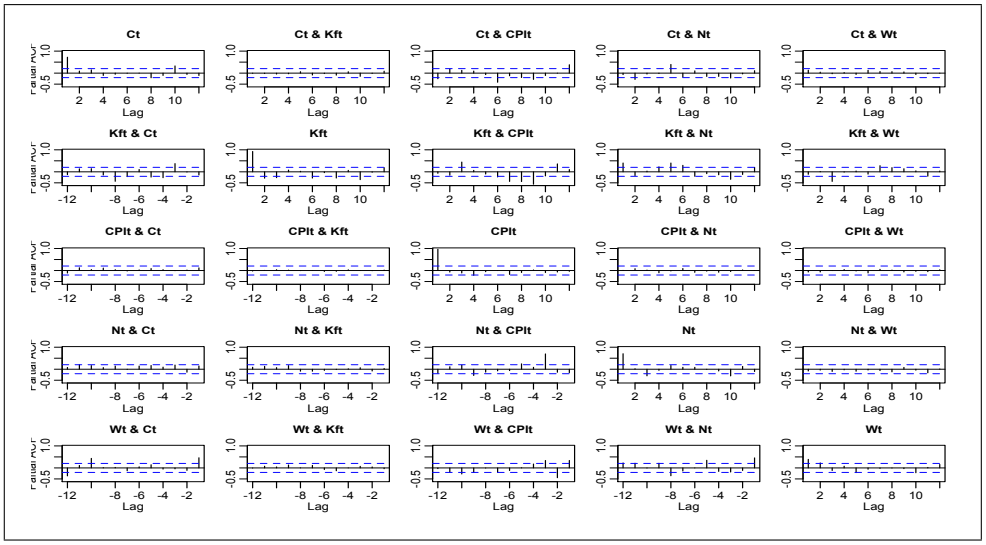
The Effect of Unconventional Fiscal Policy Sequence

We use the data before the first annoucement (1994 Q1 2012 Q2) of the uncoventional fiscal policy to train the VAR model.

First, the VAR order choosen by information criteria (AIC, BIC, hq) is either 1 or 3 or 12.

Second, refine the model and perform model checking. A refined VAR(3) model is best fitted. The model checking results can be seen in Appendix A-2.

Figure 7: Pacf Plots of $\{C_t, Kf_t, N_t, P_t, W_t\}$



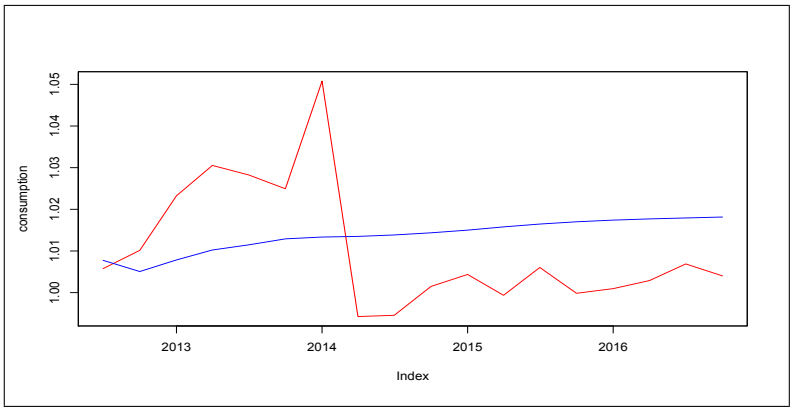
Next, we compute 1-step to 18-step at forecast origin 2012 Q2. The prediction of consumption index is generated as in table 2:

Table 2: Prediction of refined VAR(3) at Forecast Origin 2012 Q2

Date	C_t	Kf_t	CPI_t	N_t	W_t
2012 Q3	1.008	1.055	0.998	1.003	1.018
2012 Q4	1.005	1.050	0.998	1.001	1.015
2013 Q1	1.008	1.049	0.996	1.000	1.014
2013 Q2	1.010	1.049	0.996	1.004	1.015
2013 Q3	1.011	1.048	0.996	1.007	1.017
2013 Q4	1.013	1.050	0.996	1.009	1.021
2014 Q1	1.013	1.051	0.996	1.010	1.023
2014 Q2	1.013	1.052	0.996	1.011	1.025
2014 Q3	1.014	1.053	0.996	1.010	1.025
2014 Q4	1.014	1.053	0.995	1.010	1.026
2015 Q1	1.015	1.053	0.995	1.010	1.026
2015 Q2	1.016	1.053	0.995	1.010	1.026
2015 Q3	1.016	1.053	0.995	1.010	1.027
2015 Q4	1.017	1.052	0.995	1.011	1.027
2016 Q1	1.017	1.052	0.995	1.011	1.028
2016 Q2	1.018	1.051	0.995	1.011	1.029
2016 Q3	1.018	1.050	0.995	1.011	1.029
2016 Q4	1.018	1.049	0.995	1.011	1.029

Plot the real world consumption index and the predicted consumption index in the same plot, we find that the unconventional fiscal policy sequence generates high consumption in the short term will actually decreases the consumption persistently after the first exercise date. The results are shown in Figure 8.

Figure 8: Real Consumption Index vs Predicted Consumption Index
Real Wold Value: Red; Predicted Value: Blue



The Effect of Unexpected Postpoing Shock

We use the data before the first postponement (1994 Q1 2014 Q4) of the unconventional fiscal policy to train the VARX model.

First, set the lag of exogenous variables to be 0 and the VAR order choosen by information criteria (AIC, BIC, hq) is either 1 or 4.

Second, refine the model and perform model checking. A refined VARX(4) model is best fitted. The model checking results can be seen in Appendix A-2

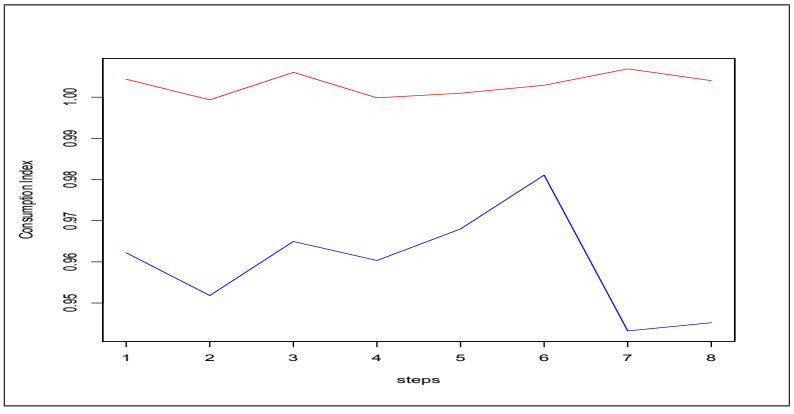
Next, we compute 1-step to 8-step at forecast origin 2014 Q4. The prediction of consumption index is generated as in table 3.

Plot the real world consumption index and the predicted consumption index in the same plot, we find that the postponement of the second unconventional fiscal policy actually dragged consumption to a higher level than if the policy were not postponed. The results are shown in Figure 9.

Table 3: Prediction of refined VARX(4) at Forecast Origin 2014 Q4

Date	C_t	Kf_t	CPI_t	N_t	W_t
2015 Q1	0.96220	1.08924	1.04229	0.98412	1.01161
2015 Q2	0.95182	1.05090	1.03800	0.97611	1.00208
2015 Q3	0.96495	1.03367	1.02872	0.96073	0.99367
2015 Q4	0.96033	1.02016	1.02538	0.96578	0.97796
2016 Q1	0.96799	1.01562	1.01733	0.96524	0.97573
2016 Q2	0.98107	1.01863	1.00944	0.97240	0.96985
2016 Q3	0.94322	0.96572	1.01203	0.97977	0.98021
2016 Q4	0.94521	0.93312	1.00411	0.97933	0.98441

Figure 9: Real Consumption Index vs Predicted Consumption Index
Real Wold Value: Red; Predicted Value: Blue



6 Conclusion

Through the empirical tests, we find that the treatment effect of the whole unconventional fiscal policy sequence is not idea. The pre-annoucement of tax increases generate high consumption in the short time, but after the first exercise day, consumption drops shaply and haven't recovered to the same level if the policy were not conducted. This phenomenon may raise from the fact that unconventional fiscal policy squeezed the future consumption to the short term. After the households cornered large amount to durable goods such as household applience, cars etc., they have no incentive to buy more. The replacement period of durable goods are long, thus even when they expected another tax increase in the near future, they have no incentive to store more.

We also find that the treatment effect of postponement is idea. The postponements of the second unconventional fiscal policy actually dragged consumption to a higher level than if the policy were not postponed. This phenomenon may raise from the fact that if the policy were not postponed, the whole VAT policy sequence may already ternimated in November 2015. Houslds might finish their shopping lists of durable goods and have no plan to buy no ones in the next several years. Thus, in our prediction period, households have no incentive to spend much and the predicted consumption remains a low lever. Thus, in this sense, postponements on the second tax increase gernerates persistent policy sequences and persistent inflation expectation. Thus the unexpected postponement have positive effects on Janpanese economy.

References

Correia, Isabel, Emmanuel Farhi, Juan Pablo Nicolini, and Pedro Teles, "Unconventional fiscal policy at the zero bound," *The American Economic Review*, 2013, *103* (4), 1172–1211.

Debortoli, Davide and Ricardo Nunes, "Fiscal policy under loose commitment," *Journal of Economic Theory*, 2010, *145* (3), 1005–1032.

DAcunto, Francesco, Daniel Hoang, and Michael Weber, "Inflation expectations and consumption expenditure," *Unpublished manuscript, University of Chicago*, 2015.

_ , _ , and _ , "The effect of unconventional fiscal policy on consumption expenditure," Technical Report, National Bureau of Economic Research 2016.

Eggertsson, Gauti B and Michael Woodford, "Policy options in a liquidity trap," *The American Economic Review*, 2004, *94* (2), 76–79.

_ and _ , "Optimal monetary and fiscal policy in a liquidity trap," in "NBER International Seminar on Macroeconomics 2004" The MIT Press 2006, pp. 75–144.

Feldstein, Martin, "The role for discretionary fiscal policy in a low interest rate environment," Technical Report, National Bureau of Economic Research 2002.

Galí, Jordi, *Monetary policy, inflation, and the business cycle: an introduction to the new Keynesian framework and its applications*, Princeton University Press, 2015.

Hall, Robert E, "The long slump," *The American Economic Review*, 2011, *101* (2), 431–469.

Hayashi, Fumio, "Measuring Depreciation for Japan: Rejoinder to Dekle and Summers," Technical Report, National Bureau of Economic Research 1991.

Nomura, Koji and Fumio Momose, "Measurement of depreciation rates based on disposal asset data in Japan," *Working Party on National Accounts of OECD, OECD STD/CSTAT/WPNA (2008)*, 2008, *9*.

APPENDIX

A-1 Model Appendix

Assume that there is a representative household with preferences described over aggregate consumption C_t and leisure L_t ,

$$E_0 \sum_{t=0}^{\infty} \beta^t u(C_t, L_t, \xi_t) \tag{A.1.1}$$

where ξ_t is a preference shock.

As suggested by Correia et al. (2013), an equilibrium for $\{C_t, L_t, N_t, K_t\}$, $\{p_t, P_t, W_t, U_t\}$, and $\{i_t \geq 0, \tau_t^c, \tau_t^n, \tau_t^k, s_t^I, \tau_t^d\}$ is characterized by the following equations:

$$N_t = 1 - L_t \tag{A.1.2}$$

where N_t is the total labor with total time endowment normalized to one. For households:

$$\frac{u_C(C_t, L_t, \xi_t)}{u_C(C_t, L_t, \xi_t)} = \frac{1 + \tau_t^c}{1 - \tau_t^n} \frac{P_t}{W_t} \tag{A.1.3}$$

where τ_t^c is tax rate on consumption, τ_t^n is tax rate on labor income P_t is the price level and W_t is the nominal wage.

$$\frac{u_C(C_t, L_t, \xi_t)}{(1 + \tau_t^c)P_t} = (1 + i_t) E_t \frac{\beta u_C(C_{t+1}, L_{t+1}, \xi_{t+1})}{(1 + \tau_{t+1}^c)P_{t+1}} \tag{A.1.4}$$

where $(1 + i_t)$ is the gross nominal interest rate.

$$\frac{u_C(C_t, L_t, \xi_t)}{(1 + \tau_t^c)} = E_t \frac{\beta u_C(C_{t+1}, L_{t+1}, \xi_{t+1})}{(1 + \tau_{t+1}^c)} [\frac{1 - s_{t+1}^I}{1 - s_t^I}(1 - \delta) + \frac{(1 - \tau_{t+1}^k)\frac{U_{t+1}}{P_{t+1}} + \tau_{t+1}^k \delta}{1 - s_t^I}] \tag{A.1.5}$$

where s_t^I is the investment tax credit, τ_t^k is the tax rate on capital income, δ is the depreciation, U_t is the rental cost of capital.

Assume each variety is produced by a monopolist. Prices are set as in Calvo(1983). Every period, a firm is able to revise the price with probability $1 - \alpha$. For firms:

$$P_t = [(1 - \alpha) p_t^{1-\theta} + \alpha P_{t-1}^{1-\theta}]^{\frac{1}{1-\theta}} \tag{A.1.6}$$

where p_t is chosen by those firms to maximize profits net of taxes.

$$p_t = \frac{\theta}{\theta - 1} E_t \sum_{j=0}^{\infty} \eta_{t,j} \frac{W_{t+j}}{A_{t+j} F_n(\frac{K_{t+j}}{N_{t+j}})} \tag{A.1.7}$$

where $\theta > 1$ is the elasticity of substitution between varieties, A_t is an aggregate

productivity shock, F is the production function, K_t is the capital stock and

$$\eta_{t,j} = \frac{(\alpha\beta)^j \frac{(1-\tau^d_{t+j})u_C(t+j)}{1+\tau^c_{t+j}}(P_{t+j})^{\theta-1}Y_{t+j}}{E_t \sum_{j=0}^{\infty}(\alpha\beta)^j \frac{(1-\tau^d_{t+j})u_C(t+j)}{1+\tau^c_{t+j}}(P_{t+j})^{\theta-1}Y_{t+j}} \tag{A.1.8}$$

where τ^d_t is the tax rate on profits.

And

$$C_t + G_t + K_{t+1} - (1-\theta)K_t = [\sum_{j=0}^{t+1} \varpi_j (\frac{p_{t-j}}{P_t})^{-\theta}]^{-1} A_t F(K_t, N_t) \tag{A.1.9}$$

where G_t is public consumption, where ϖ_j is the share of firms that have set prices j periods before, $\varpi_j = \alpha^j(1-\alpha), j = 0, 1, 2, ..., t$, and $\varpi_{t+1} = \alpha^{t+1}$, which is the share of firms that have never set prices so far.

A-2 Estimation Appendix

Model Checking for VAR

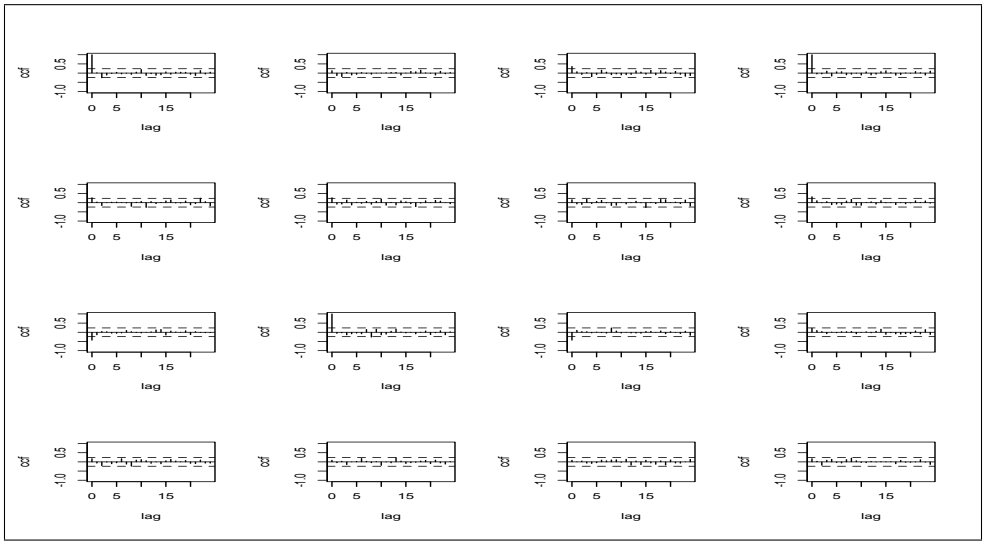


Figure 10: ccf plots of VAR(3)

From the ccf plots and the p-value plots, we find that a refined VAR(3) is adequate enough to fit the data.

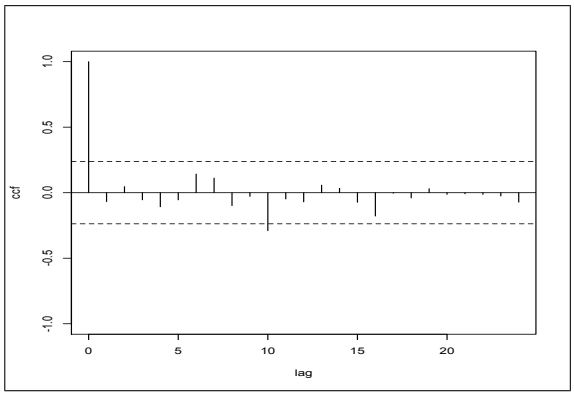


Figure 11: ccf of VAR(3) continue

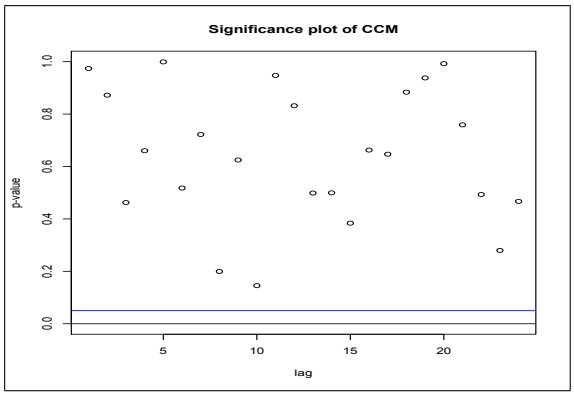


Figure 12: p-value for each ccm of VAR(3)

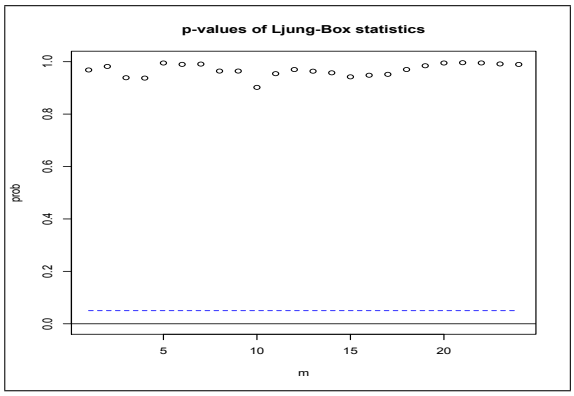


Figure 13: MQ Statiscis of VAR(3)

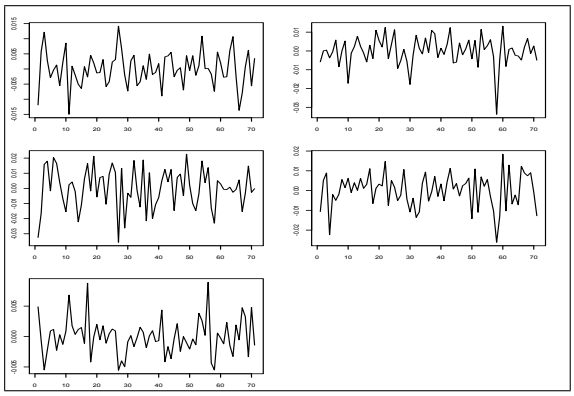


Figure 14: Residual Plots of VAR(3)

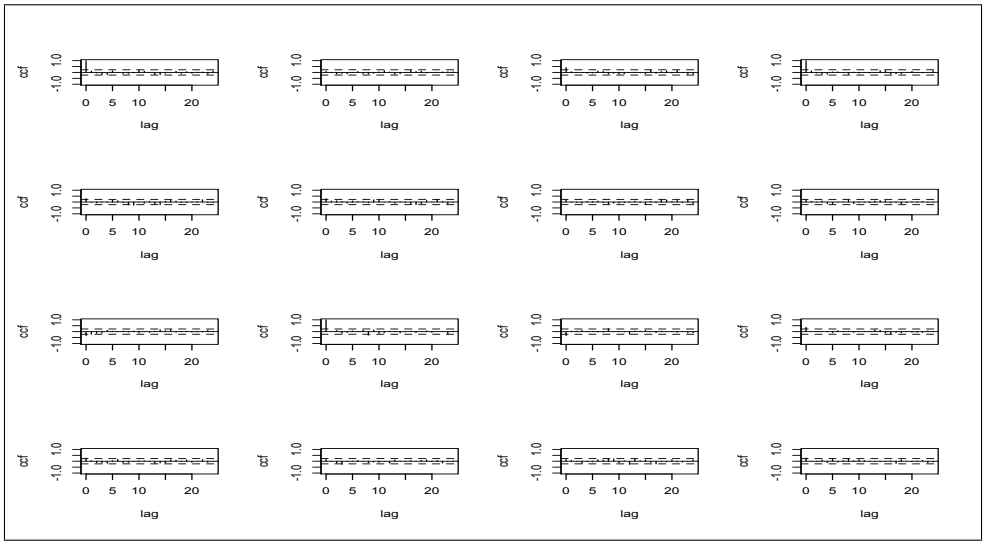


Figure 15: ccf plots of VARX(4)

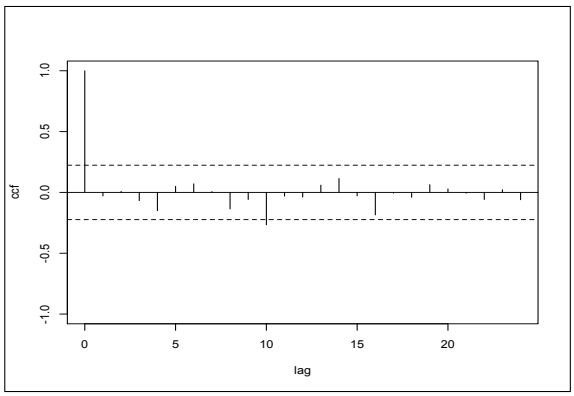


Figure 16: ccf of VARX(4) continue

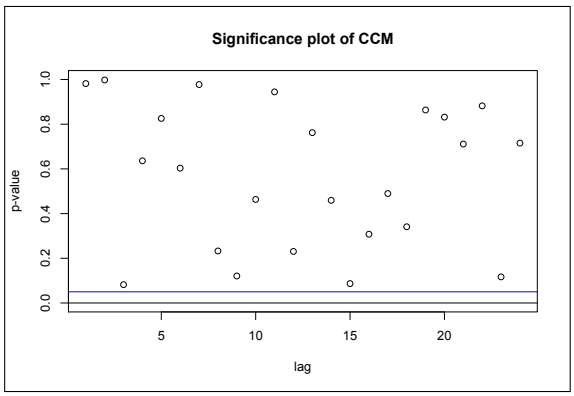


Figure 17: p-value for each ccm of VARX(4)

Model Checking for VARX

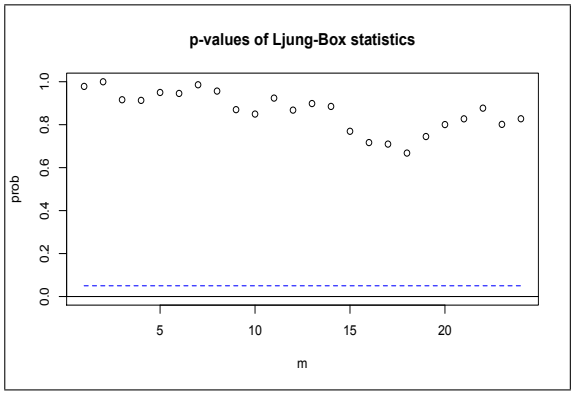


Figure 18: MQ Statiscis of VARX(4)

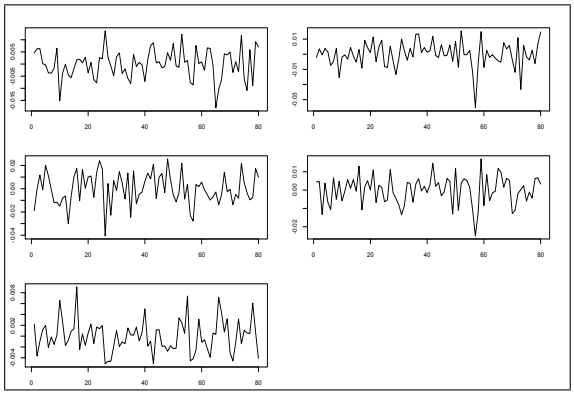


Figure 19: Residual Plots of VARX(4)

From the ccf plots and the p-value plots, we find that a refined VARX(4) is adequate enough to fit the data.