On the Role of Demand Shock and Supply Shock for the Japanese Business Cycle*

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1. **INTRODUCTION**

The purpose of this study is to assess the empirical importance of the aggregate demand shock and supply shock for the Japanese business cycle from 1973 to 1985, using a simple rational expectations-natural rate model.

There already exist several studies, such as Seo and Takahashi (1981), Hamada and Hayashi (1985), and Gochoco (1986) which applied the rational expectations-natural rate model for the Japanese economy. A notable fact is that the neutrality hypothesis was almost unanimously rejected in these researches. However, as Gochoco (1986) noticed, the presence of nearly vertical Japan's Phillips curve for the period, 1974—1982, found in Hamada and Hayashi (1986 : 104) may still leave us some room for further investigations. Furthermore, this work concerns with the business cycle fluctuations of the Japanese economy from 1973 to 1985. This period is well known for the fact that most of the industrialized countries suffered sharp increases in the price of oil engineered by the OPEC cartel; oil

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1. For an excellent survey of the literature for the Japanese economy, see Okina (1984).
2. Exceptions are Parkin (1984) and Kama (1985). However Parkin's conclusion is drawn from the Granget test, not Barro (1977) type test. For the relation between these tests, see Mishkin (1983 : 51—56). Kama uses rather different specification, actually much simpler one, for the money forecasting equation. His specification of output equation also differs from ours.
3. Suzuki (1983 : 100—104) lists several other empirical studies, sharing same conclusion.
The first oil shock occurred in 1973–1974, when the nominal price of oil jumped from $3.50 per barrel to about $13.00 per barrel. The second oil shock happened in 1979–1980, when its price climbed almost to $35.00 per barrel. For the Japanese economy, by the first oil shock yen price of oil have only trebled due to the appreciation of the exchange rate. But, due to the second oil shock, it also have gone up three times because of the depreciation. Moreover, imported oil counted more than 99% of the total oil supply for the Japanese economy in 1973, in contrast with only 20% for the United States, thus these enormous rises of the oil price should deserve serious attentions in any study of the economic fluctuations for the Japanese economy. However previous applications of the rational expectations-natural rate model for the Japanese economy may not have properly specified these supply shocks. For example, Hamada and Hayashi included a kink of time trend of real output and dummy variable to represent the effects of the supply shock. Nevertheless, in this formulation, supply shock is restricted to affect only the natural rate level of real output and thus its effects on business cycle fluctuations are not explicitly taken into account. Seo and Takahashi also incorporated a kinked time trend of real output and supplemented the log of the oil price to capture the effects of supply shock. Nonetheless, this formula conceal the issue that a distinction between the anticipated changes of the relative price of energy and unanticipated changes is critical in the application of the rational expectations-natural rate model. Finally, Gochoco who studied almost same sample period, 1973–1985, as ours, had no explicit consideration for such shocks and this is the case with

4. Supply shock, in general, includes not only energy price shock, but also productivity slowdown and food price shock. However, in this study, only energy price shock is focused. Furthermore, we are only examining a period after the first oil shock. For an analysis of the importance of the supply shock for the pre-first oil shock period, see Hamilton (1983) which also contained analyses of the exogeneity of the supply shock.
most of the rest of the investigations. In this study we propose a different specification of the supply shock within a simple rational expectations-natural rate model.

Another issue which we are concerned with, is that these previous applications for the Japanese economy have used monetary shock as representing aggregate demand shock. However, Gordon (1982: 1105) raises an issue that this method needs an implicit assumption that velocity is a serially uncorrelated random variable; He found that this assumption did not fold in his study. With the results of former inquiries using monetary shock in mind, a different specification of the aggregate demand shock may be worth examining.

Based on these two reflections, we use a model in line with Froyen and Waud (1985). The model has two features. First one is that this model contains an explicit modelling of the supply shock so that it allows us to examine the effects of both anticipated changes of the relative price of energy and unanticipated changes. Second feature is that in this framework, with a specific assumption, nominal income shock, not monetary shock as in the most of the previous studies except Hiruma (1988), is taken to be the aggregate demand shock.

The structure of this study is the following. In section 2, the model is briefly sketched. Data sources are given in section 3. In section 4, several issues of empirical specifications are discussed. The aggregate demand

5. For a theoretical explanation along this line, see, for example, Cukierman (1984: 177, fn.5).

6. Lawrence (1983) also explicitly treated supply shock in his analysis. However, in his framework supply shock is just identified as the residual portion of Lucas supply function. Compared with this type of approach, Froyen and Waud approach seems to have an advantage of examining a concrete measure of supply shock.

7. However, a focus in his study is given on the price equation.
shock and supply shock were examined in section 5. In section 6, three components of the aggregate demand shocks; monetary shocks, fiscal shocks, export shocks were investigated. Final section contains a summary of the study.

2. THE MODEL

First for a demand function, (all variables are defined in logarithmic terms),

\[(1) y_t^d = -P_t + X_t \]

where

- \( y_t^d \) = demand for real output at time \( t \);
- \( P_t \) = general price level at time \( t \);
- \( X_t \) = an exogenous shift variable;

is postulated. Here, by assuming a unit elastic aggregate demand curve, as in Lucas (1973), \( X_t \) is taken to be nominal income. (8) Assuming Cobb-Douglas production function with three factors of production, labor, capital, and energy, it is possible to derive following Lucas type of supply function,

\[(2) y_t^s = \alpha + \beta (P_t - E_\ell - 1 P_t) - \delta (R_t - P_t) + \gamma K_t \]

where

- \( y_t^s \) = supply of real output at time \( t \);
- \( R_t \) = energy price at time \( t \);
- \( K_t \) = capital stock at time \( t \);

8. Lawrence (1983: 229, fn.3) mentions that a sufficient condition for this would be if the consumption-income and money demand-income elasticities were respectively unity. See also M. Friedman (1971), for the theoretical foundations.

9. It is also possible to derive same type of specification from CES production function with special assumptions, see, for example, Bruno-Sachs (1985: 90).
\( E_{t-1}P_t \) = expectation of \( P_t \) based on information available at time \( t-1 \);
\( \alpha, \beta, \delta, \gamma = \text{constants.} \)

Now it is simple to deduce following output equation by equating aggregate demand and supply with the rational expectations imposed.

\[
(3) y_t = \alpha - \delta E_{t-1} (R_t - P_t) + \gamma K_t \\
+ \frac{\beta}{1 + \beta} (X_t - E_{t-1}X_t) - \frac{\delta}{1 + \beta} \{ (R_t - P_t) - E_{t-1} (R_t - P_t) \}
\]

\( X_t - E_{t-1}X_t \), and \( (R_t - P_t) - E_{t-1} (R_t - P_t) \) are the aggregate demand shock and supply shock, respectively. We postulate that capital stock follows a linear time trend. Following Froyen and Waud first three terms in equation (3) determine the natural rate level of real output. It must be noticed that \( E_{t-1} (R_t - P_t) \) is included here because it is the anticipated relative price level. Thus the natural rate level of real output becomes,

\[
(4) y_{nt} = \tau_0 - \tau_1 E_{t-1} (R_t - P_t) + \tau_2 \text{Trend}
\]

where

\( \text{Trend} = \text{time trend} \);
\( \tau_0, \tau_1, \tau_2 = (\text{positive})\text{constants}; \)

and the cyclical fluctuations of real output becomes,

\[
(5) y_{ct} = \tau_3 (X_t - E_{t-1}X_t) - \tau_4 \{ (R_t - P_t) - E_{t-1} (R_t - P_t) \}
\]

where

\( \tau_3, \tau_4 = (\text{positive})\text{constants}; \)

We might recall that in these formulations anticipated component of energy price level affects the natural rate level of real output, while supply shock and demand shock have influences upon cyclical fluctuations.
3. DATA SOURCES

Following data sources are employed in this study.


(2) Relative price of energy; Energy prices for quarterly data were calculated from monthly data of Petroleum, Coal and Natural Gas Prices in Import Price Indexes for Basic Groups by Groups in Commodities, Weights and Linked Indexes of 1985 Base Wholesale Price Indexes, 1988, by Research and Statistics Department of the Bank of Japan. GNP deflators are from Annual Report of National Accounts (1982, 1986, 1987, 1989). The relative prices of energy are given by energy price deflator divided by GNP deflator (relative price of energy at 1970 = 1.00).


4. EMPIRICAL SPECIFICATIONS.

In this section, some of the problems encountered in our investigation will be discussed.

10. Parkin (1984) sustains that the tests with seasonally adjusted data can be biased towards a rejection of the neutrality hypothesis. However, Mishkin (1983) claims that both data series lead to same conclusion at least for the United States.
4.1 Recursive Structure of the Japanese Economy

Aggregate demand equation (1) assumes that nominal income is exogenous. In other words, the structure of the economy is recursive in the sense that disturbances flow from nominal income to prices, not back to income. And the division of exogenous shifts in nominal income into output change and price change is simultaneously determined with the supply side of the economy, where the discrepancy between expected and unexpected price change is critical. Froyen and Waud (1985: 10) cites Nelson (1979) for this assumption. Thus, following Nelson (1979: 1317), the recursive structure hypothesis for the Japanese economy was examined by a direct test by Granger's (1969) definition: whether lagged values of one variable remain significant in a regression of the other with its own lagged values. In a regression of inflation rate (first difference of the logarithm of the price level) on five of its own lagged values and on one lagged growth rates of nominal income for the period from 1973: I to 1985: IV, the t value of the one lagged growth rate of nominal income was 2.98 which is significant at the 1% level. However, in a regression of growth rate of nominal income on three of its own lagged values and from one to five lags of inflation rate, none of the lagged inflation rates were significant, individually nor jointly. Thus according to this simple test, the assumption of the recur-

11. Nelson also examined Sim's (1972) test as well as Pierce and Haugh (1977) test.
12. Estimates result was,
\[ DP_t = .448DP_{t-1} + .017DP_{t-2} - .220DP_{t-3} + .722DP_{t-4} - .487DP_{t-5} + .298DY_{t-1} \]
\[ ( .123) ( .085) ( .087) ( .087) ( .111) ( .100) \]
\[ R^2 = .92 \quad \sigma = .011 \quad Q(21) = 21.12 \]
13. Estimated result only with lagged dependent variables was,
\[ DY_t = .266DY_{t-1} + .465DY_{t-2} + .227DY_{t-3} \]
\[ ( .138) ( .124) ( .134) \]
\[ R^2 = .380 \quad \sigma = .011 \quad Q(21) = 13.44 \]
sive structure may not be at odds for the Japanese economy.

4.2 SAMPLE PERIOD

In this study we focus upon the flexible exchange rate years from 1973 to 1985. Another justification for excluding earlier years may be given by the existence of a kink in time trend of real GNP found in Seo and Takahashi (1981). A reason to end in 1985 is the consideration of the alleged collapse of the O. P. E. C. system in 1986.

4.3 AN ADJUSTMENT LAG

As in most of the researches using this approach, serial correlation problem of the cyclical component of real output is not absent in this study. Here we adopt Lucas's (1973) specification of adding lagged value of the dependent variable to represent this problem. Hence, real output equation for its cyclical component finally becomes,

\[
(6) Y_{ct} = \tau_3 (X_t - E_{t-1} X_t) + \tau_4 \{ (R_t - P_t) - E_{t-1} (R_t - P_t) \} + \lambda Y_{c(t-1)}
\]

where

\[
\lambda = \text{a constant}.
\]

4.4 THE AGGREGATE DEMAND SHOCK

In Froyen and Waud (1985), following stochastic process was assumed for nominal income,

\[
(7) X_t = X_{t-1} + \eta_0 + \eta_1 \text{ Trend}
\]

14. Gordon (1982 : 1095-1096) advocates this method for correction of residual serial correlation. First, this method avoids a need for statistical serial correlation correction that plagued the previous studies. Second, this method makes it possible to by-pass the troublesome observational equivalence problem by assuming that only current component of shocks appears in the output equation.
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where
\[ \eta_0, \eta_1 = \text{constant}; \]

and the residuals from this equation were identified as the aggregate demand shock in their model, Froyen and Waud (1985: 12). Though this specification of nominal income process was applicable and in fact used in a former version of this study, this formulation appears to be rather ad-hoc. Hence in this study, instead following autoregressive process was assumed,

\[ (8) DX_t = \eta_0 + \sum_{i=0}^{n} \eta_i DX_{t-i} \]

where
\[ D = \text{Difference operator} (DZ_t = Z_t - Z_{t-1}); \]

Residuals from this equation are regarded to be our measures of the aggregate demand shock, ADS_t.

4.5 SUPPLY SHOCK

In Froyen and Waud (1985: 10), following stochastic process for the relative price of energy was assumed.

\[ (9) R_t - P_t = \phi(t) + \mu_t, \quad \mu_t \sim N(0, \sigma^2, \mu) \]

where
\[ \phi(t) = \text{a linear time trend in the relative price of energy}; \]

And this residual \( \mu_t \) was defined to be supply shock which affects cyclical fluctuations of real output and \( \phi(t) \) term influences the natural rate level of real output in their model. In their theoretical presumption, this supply shock was supposed to be serially uncorrelated. But in fact, this variable was serially correlated. Since this is nothing but cyclical (or detrended) component of the relative price of energy, this serial correlation property should not be such surprise. In Froyen and Waud (1983: 16), they re-specified
stochastic process of supply shock as a first order autoregressive process. Then they decomposed original supply shock into anticipated and unanticipated components. And they examined the effects of anticipated and unanticipated supply shock for the business cycle fluctuations. This procedure has some problem. In their model, only trend component of the relative price of the energy will have effects on the natural rate level of real output, nonetheless, anticipated supply shock is in fact anticipated when public make the expectation formation. This is precisely the reason that anticipated supply shock and trend component have same coefficients in their model, Froyen and Waud (1983 : 16). It is apparent that this anticipated supply shock should also determine the natural rate level of real output, not the cyclical fluctuations.

Furthermore, another issue is that autoregressive process for the detrended relative price of energy was found to be nonstationary in our case. Hence, based on these considerations, we assume following autoregressive process for the relative price of energy,

\[ D(R_t - P_t) = \xi_0 + \sum_{i=1}^{m} \xi_i D(R_{t-i} - P_{t-i}) \]

where

\[ \xi_i = \text{constants} \]

Expected value from this equation plus one lagged value of the relative price, that is, expected level of the relative price of at energy, \( ERP_t \), is used

15. However, in Froyen and Waud (1985), (1987), they somewhat ignored this important difference, by only focusing on \( \mu \), variable.

16. In a former version of this study, we used import price measure of the supply shock. In that case, first order autoregressive process was sufficient to get white noise. This makes a contrast with Froyen and Waud case, where only first order autoregressive process was needed for both import price measure and energy price measure of the supply shock.
for $E_{t-1}$ $(R_t-P_t)$ in equation (4). Hence unlike Froyen and Waud, the anticipated movements of the relative price of energy only affect the natural rate level of real output, not cyclical fluctuations. And residuals from this equation were taken to be supply shocks, $SS_t$ in this study. To sum up, our model consists of following equations.

\begin{align*}
\langle 1 \rangle y_{nt} &= \tau_0 - \tau_1 ERP_t + \tau_2 \ 	ext{Trend} \\
\langle 2 \rangle DX_t &= \gamma_0 + \sum_{i=0}^{m} \eta_i DX_{t-i} + ADS_t \\
\langle 3 \rangle D(R_t-P_t) &= \xi_0 + \sum_{i=1}^{m} \xi_i D(R_{t-i}-P_{t-i}) + SS_t \\
\langle 4 \rangle y_{ct} &= \tau_3 ADS_t + \tau_4 SS_t + \lambda y_{ct-1}
\end{align*}

In the next section, estimated results for these equations will be reported.

5. **DEMAND SHOCK AND SUPPLY SHOCK FOR THE JAPANESE BUSINESS CYCLE**

5.1 **ENERGY PRICE EQUATION**

An estimation of an autoregressive regression for these relative prices of energy for the period from 1973: I to 1985: IV yielded following result, with the standard errors in parentheses,

\begin{align*}
\langle 15 \rangle D(R_t-P_t) &= .396 \ D(R_{t-1}-P_{t-2}) + .334 \ D(R_{t-2}-P_{t-2}) \\
&\quad + .134 \quad (.138) \\
&\quad + .362 \ D(R_{t-3}-P_{t-3}) \\
&\quad (.135) \\
R^2 &= .25 \quad \sigma = .104 \quad Q(21) = 11.53
\end{align*}

\( \sigma \) is the standard error of the regression. Constant term was found to be insignificant in this equation since relative price was normalized so that the log of relative price of energy in 1970 is equal to zero. Additional lagged values were insignificant when added to this equation. \( Q(21) \) is the Ljung-
Box statistics which is distributed as a chi-square with 21 degrees of freedom. According to this statistics, the null hypothesis that true residuals are white noise is not rejected at the 10% level of the significance. Predicted values from this equation plus one lagged value of relative price of energy is regarded as $ERP_t$ as mentioned before and the residuals are interpreted as our measure of supply shock, $SS_t$.

5.2 THE NATURAL RATE LEVEL OF REAL OUTPUT

The log of real GNP is regressed upon constant, time trend, and expected level of the relative price of energy to get cyclical components of real output and the estimated result of this regression for our sample period was,

$$U6)Y_t = 12.08 + .109 \text{Trend} - 0.35 ERP_t$$

$$\begin{align*}
&\text{(0.005)} \quad\text{(0.002)} \quad\text{(0.007)} \\
R^2 = .99 &\quad \sigma = .014 \quad D-W = .467
\end{align*}$$

Residuals from this equation are considered to be business cycle fluctuations of real output.

5.3 NOMINAL INCOME EQUATION

Growth rates of nominal income over the sample period were regressed against constant and its own lagged values and the estimated result is,

$$U7)DY_t = .006 + .256 DY_{t-1} + .452 DY_{t-2}$$

$$\begin{align*}
&\text{(0.003)} \quad\text{(0.126)} \quad\text{(0.124)} \\
R^2 = .39 &\quad \sigma = .109 \quad Q(21) = 14.1
\end{align*}$$

where

$Y_t =$ log of nominal income at time $t$;

Additional lagged values are not significant in this equation. Presence of
residual serial correlation problem was not suggested by $Q$ statistics. Residuals from this equation are regarded as the aggregate demand shock.

5.4 **JAPANESE BUSINESS CYCLE**

Now it seems that we are in a final position to examine Japanese business cycle; but we faced with one more cumbersome problem. The problem is that, as in Froyen and Waud (1985: 13), Lucas method for the correction of serially correlated error terms did not completely settle the issue. Thus we used Maximum Likelihood Grid Procedure method of RATS program to correct remaining problem. The estimated result for the cyclical output equation (14) was,

\[
Y_{ct} = 0.567 \text{ADS}_t - 0.026 \text{USS}_t + 0.531 Y_{ct-1} + 0.754 \rho_{t-1}
\]

\[
 (.073) \quad (.006) \quad (.119) \quad (.125)
\]

$R^2 = .85 \quad \delta = .005 \quad Q(21) = 21.27$

According to $Q$ statistics, the while noise error hypothesis is not rejected at the 10% level. $T$ values for the aggregate demand shock, supply shock and lagged value of cyclical component of real output are respectively, 6.99, 3.98, and 4.47. As we expected, supply shock is significant at the 1% level in accounting the Japanese business cycle from 1973: I to 1985: IV. Further, in this framework, the aggregate demand shock is also surprisingly significant at the 1% level. A curious finding from the observation of the time series of the aggregate demand shock is that the variability of the aggregate demand shock seems to be substantially reduced roughly from 1978. In fact, the variance of the aggregate demand shock for the second period from 1978: III to 1985: IV is .00002 which is less than one tenth of the variance of the first period, .0003. This issue will be discussed in the next section.

17. Second lagged dependent variable was not significant when added to this equation.
section with specific aggregate demand shock components.

6. **MONETARY SHOCKS, FISCAL SHOCKS, EXPORT SHOCKS AND BUSINESS CYCLE**

Stimulated by the result in the last section, specific aggregate demand shock components will be examined in this section. Traditional position of the monetarist, such as Friedman (1971), is that principal determinant of nominal income is money, as shown in Anderson and Jordan (1968). Actually, the results of Mishkin (1983) reveal that nominal income shock model and monetary shock model basically concede the same conclusion for the rational expectations-natural rate hypothesis. Also the result of Grossman (1979) who used nominal income shock model, agrees with the result of Barro's (1977), (1978), monetary shock model. Nevertheless, we suspect that the ignorance of the openness of the Japanese economy may be potentially serious. Hence, though rather ad hoc, we will examine three potential aggregate demand shock components; monetary shock, fiscal shock, and export shock with the same framework used in the last section. First univariate time series models were estimated for money supply, fiscal expenditure, and real export respectively to get approximations for the unanticipated movements of these variables. For the money supply, an estimated result of ARIMA(1,1,3) model was,

\[
(1 - 0.748B)(1 - B)M_t = 0.014 + (1 - 1.132B + 0.560B^2 - 0.644B^3)\epsilon_t
\]

\[
(0.055) (0.003) (0.134) (0.178) (0.151)
\]

\[R^2 = 0.43 \quad \sigma = 0.17 \quad Q(21) = 16.21\]

where

\[M_t = \text{log of nominal money supply} ;\]

\[B = \text{lag operator} ;\]

For the fiscal expenditure, an estimated result of ARIMA(1,1,1) model
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was,

$$\Phi_0 (1 + .898B)(1 - B) G_t = .009 + (1 + .904B) \varepsilon_t$$

(0.087) (0.001) (0.118)

$$R^2 = .095 \quad \sigma = .007 \quad Q(21) = 15.02$$

where

$$G_t = \text{log of real government expenditure;}$$

For the real exports, an estimated result of ARIMA(2,1,2) was,

$$\Phi_1 (1 - .232B + .643B^2)(1 - B) EX_t = .022 + (1 + .051B + .856B^2) \varepsilon_t$$

(0.121) (0.102) (0.005) (0.103) (0.091)

$$R^2 = .235 \quad \sigma = .029 \quad Q(21) = 18.3$$

where

$$EX_t = \text{log of real export;}$$

According to Q statistics, in these equations, white noise error hypothesis is not rejected at the 10% level of significance. The residuals from these equations are taken to be monetary shocks, $$UM_t$$, fiscal shocks, $$UG_t$$, and export shocks, $$UEX_t$$, respectively. Using these shocks, fiscal shock was found not to be significant in the cyclical output equation. Thus our final result for the Japanese business cycle fluctuations was,

$$\Phi_2 y_{ct} = .129 UM_t + .109 UEX_t - .043SS_t + .827 y_{ct-1}$$

(0.062) (0.037) (0.011) (0.076)

$$R^2 = .70 \quad \sigma = .007 \quad Q(21) = 17.92$$

where

$$UM_t = \text{unanticipated money growth rates;}$$

$$UEX_t = \text{unanticipated growth rates of exports.}$$

T values for the monetary shock, export shock, supply shock, and lagged value of cyclical output are respectively, 2.07, 2.93, −4.54, 10.67. A
serial correlation problem of the error term may not be relevant in this result according to $Q$ statistics. As in the last section, supply shock is significant at the 1% level. Furthermore, while export shock is significant at the 5% level, monetary shock is significant at the 5% level as well. In the last section, it was mentioned that the variability of the aggregate demand shock in the form of the nominal income shock was greatly reduced after 1978. However it turned out that the variance of the monetary shock for the second period is .0026 which is almost same as that of the first period, .0025. In turn, for the export shock, the variance for the second period is .007 which is less than one half of the first period variance, .016. Thus the reduction of the variance of the aggregate demand shock since 1978 seems to be attributed to the decline of the variability of export shock, not of monetary shock. This fact may be at odds with the view that the Bank of Japan took a “closer monetarist” position since 1978, when it started announcements of the predicted growth rates of money supply.

7. SUMMARY

This study re-examines the importance of the supply shock as well as the demand shock for the Japanese business cycles from 1973 to 1985. We used a model which made possible for us to examine the potential effects of the supply shock much more rigorously than the former studies.

In the first part of the study, the aggregate demand shock, specified as nominal income shocks was investigated. We found that supply shock was significant in accounting Japanese business cycle as we conjectured. However, it also turned out that the nominal income shock was highly significant as well.

Stimulated by this result, in the second part of the study, aggregate demand shock components; monetary shocks, fiscal shocks, and export shocks

18. This observation is in line with Ito’s (1988) sophisticated analysis on this issue.
were examined by using time-series modelling. It was also the case where the supply shock was significant as before. Nonetheless, monetary shocks as well as export shock were found also significant. Another interesting finding was that the reduction of the variability of the aggregate demand shocks after 1978, was due to the reduction of the variance of the export shock, not of the monetary shock.

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