Nonparametric Estimation of Demand and Supply Shocks in East Asia[1]

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Abstract

This paper estimates macro demand and supply shocks causing business fluctuations in Japan, Korea, China, Taiwan, Hong Kong, Singapore, Malaysia, Indonesia and the Philippines. It uses the industry-level data of wages and index of industrial production and the nonparametric econometric model developed by Okumura (2003), which enables us to estimate the supply and demand shift variables when only intersections of supply and demand curves are observable. Subsequently, it investigates the correlation of the estimated shocks among the countries and areas to clarify their macroeconomic interdependence. Found are (1) the strong correlations of supply shocks among Japan, Korea and Taiwan, (2) the strong correlations of demand and supply shocks between Malaysia and Indonesia, and (3) the possibility of structural changes in interaction in East Asia around 1990.

Keywords: Macroeconomic interdependence, East Asia, Demand and supply shocks, Business fluctuations, Sharp bounds, Simultaneous equations, Panel data models.

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1 Introduction

This paper estimates macroeconomic demand and supply shocks causing business fluctuations in Japan, Korea, China, Taiwan, Hong Kong, Singapore, Malaysia, Indonesia and the Philippines in East Asia. It uses the industry-level data of wages and index of industrial production and the nonparametric econometric model developed by Okumura (2003), which enables us to estimate the supply and demand shift variables when only intersections of supply and demand curves are observable. Subsequently, it investigates the correlation of the estimated shocks among the countries and areas to clarify their macroeconomic interdependence. These countries and areas have achieved remarkable economic growth. However, they have also experienced business fluctuations and specifically, some of them, including Japan, have fallen into a severe recession during this decade. It is thus of vital importance to investigate what has caused business fluctuations in this area.

This area has deepened economic interdependency. Specifically: (1) due to increase in direct foreign investment and the like, technological changes have been propagated more rapidly among the countries and areas, (2) due to liberalization of trade, the trade relationship has been closer, (3) due to unification of international financial markets, one country/area's domestic macroeconomic policy has a bigger influence on the economic performance of other countries/areas, (4) due to this unification, the fluctuation in the asset prices in one country/area has a bigger influence on the asset markets in other countries/areas, as seen during the Asian currency crisis in 1997, and (5) some of them have promoted policy coordination. Thus, it is of vital importance to clarify the structure of the macroeconomic interdependency in this area.

This paper employs the nonparametric econometric model developed in Okumura (2003). Okumura (2003) presented the nonparametric econometric approach for estimating sharp bounds on the supply and demand shift variables in a simple supply and demand framework. This approach requires only observation of the intersections (prices and quantities) of the upward-sloping supply and downward-sloping demand curves. On such assumptions only, the existing parametric approaches can not identify the supply and demand shift variables due to the identification problem. This methodology thus relieves the identification and model specification problems related to estimating shift variables in a simultaneous equations model.

This econometric model of identifying the shift variables has the following intuition. In the standard supply and demand framework, when most of the cross-section observations are found in the south-east (and the north-west) region of the origin, we guess that it is likely that the supply shift variables is positive (and negative, respectively). Specifically, consider the upward-sloping supply and the downward-sloping demand functions, $f(p)$ and $g(p)$, respectively, with the disturbances, u and v, whose medians are zero, i.e.,

$$\begin{cases} q = f(p) + u \\ q = g(p) + v \end{cases},$$

Suppose that the point $(\overline{q}, \overline{p})$ whose associated disturbances are $(0,0)$ is known. If (q,p) is observed in the south-east region of $(\overline{q}+\alpha, \overline{p})$ (denoted by $SE(\alpha)$), the associated u, which is measured at the q-axis intersected by the f-function, is greater than α since $f(p)$ has the upward-sloping. In contrast, if (q,p) is observed in the north-west region of $(\overline{q}+\alpha, \overline{p})$ (denoted by $NW(\alpha)$), the associated u is smaller than α. Thus, $P((q,p) \in SE(\alpha)) \leq P(u \geq \alpha) \leq 1 - P((q,p) \in NW(\alpha))$. It implies $P((q,p) \in NW(\alpha)) \leq F_u(\alpha) \leq 1 - P((q,p) \in SE(\alpha))$, where F_u is the distribution of u. Since the distribution of u has the bounds which can be estimated, its median (denoted by $\overline{u}$) also has the bounds. That is, since $P((q,p) \in NW(\overline{u})) \leq F_u(\overline{u}) = 0.5 \leq 1 - P((q,p) \in SE(\overline{u}))$

and both $P((q,p) \in NW(\alpha))$ and $1 - P((q,p) \in SE(\alpha))$ are increasing in α, $\{\alpha \,|\, P((q,p) \in SE(\alpha)) = 0.5\} \leq \overline{u} \leq \{\alpha \,|\, P((q,p) \in NW(\alpha)) = 0.5\}$. The median of u corresponds to the supply shift variable when u corresponds to the supply shift variable plus the disturbance whose median is zero. Similarly, since $g(p)$ has the downward-sloping, the median of v, which corresponds to the demand shift variable, has the bounds. Introducing additional assumptions into the presented econometric model, the estimates of the bounds on the shift variables narrow. Bounds on the shift variables are estimated under a sequence of cumulative assumptions that have often been employed in existing parametric estimations: (1) distribution of the disturbances is symmetric around zero and (2) a normal distribution with zero mean. The basic idea of the econometric model is somewhat related to Manski (1997) and Manski and Pepper (2000).[2]

The structural vector autoregression (VAR) methods are widely used for the estimation of demand and supply shocks. Blanchard and Quah (1989) and Shapiro and Watson (1988) made the long run assumptions that demand shocks have effects only on prices, whereas supply shocks have effects on both prices and quantities to identify the aggregate demand and supply shocks. Employing their econometric models, Bayumi and Eichengreen (1993, 1994b), Kawai and Okumura (1996), Bayoumi et al. (2000), Yuen (2001), Zhang et al. (2002) and Sato et al. (2003) estimated the demand and supply shocks of the countries and areas in East Asia and investigated the interdependence of the estimated shocks among them. The econometric model of this paper and their structural VAR models differ in the assumptions for identification. These existing studies

[2] Manski (1997) and Manski and Pepper (2000) estimated the bounds on the probability that treatment response functions $h()$ at some covariate s is less than a specified constant c, i.e., $P[h(s) \leq c]$, by observing covariates, realized treatments and realized outcomes for a random sample of individuals. They assumed the prior information that response functions are monotone, semimonotone, or concave-monotone. In comparison to this, the methodology in this paper estimates the bounds on the median of the disturbance that generates the distribution of $h()$ inside the probability, in order to investigate the causes of the fluctuations of economic variables. Therefore, their and my purposes and methodologies are different.

did not use information on the relationship between shocks and equilibrium in the framework of upward-sloping supply and downward-sloping demand curves to identify the shocks; they did, however, use this information to check whether or not the estimated coefficients had plausible signs. In this paper, this more acceptable assumption is used to estimate shocks. In other words, the estimated result from different assumptions to those used in existing literature could shed a new light on this issue.

This paper is organized as follows. Section 2 discusses the econometric approach. Section 3 estimates the macro demand and supply shocks in Japan, Korea, China, Taiwan, Hong Kong, Singapore, Indonesia, Malaysia and the Philippines and subsequently investigates the interdependence of these shocks among the countries and areas. Section 4 concludes the paper.

2 The Econometric Model

This section explains the econometric model presented by Okumura (2003).

I study the following model with two endogenous variables and two disturbances to estimate the medians of the disturbances.[3]

$$\begin{cases} q = f(p) + u \\ q = g(p) + v \end{cases}, \tag{1}$$

where p and q are endogenous variables, and u and v are disturbances. The population is formalized as a measure space (J, Ω, P) of agents, with P a probability measure. Then $P[(u, v), (p', q')]$ gives the distribution of disturbances and realized variables. $f()$ and $g()$ are an increasing and a decreasing function in p, respectively, and thus, the solution (q, p) satisfying equations (1) is unique, given (u, v).

Let us choose one point $(\overline{q}, \overline{p})$ whose associated disturbances are $(0, 0)$ among the solutions satisfying equations (1) as a normalization. $NE(\alpha), SE(\alpha), NW(\alpha)$

[3] The medians of the disturbances correspond to the shift variables as we see later.

and $SW(\alpha)$ represent the northeast, southeast, northwest and southwest regions of $(\overline{q}+\alpha,\overline{p})$ for some real number α, respectively, as Figure 1 shows. Suppose (q,p) is observed in $SE\,(\alpha)$. Since the f-function is upward-sloping, u, which is measured at the q-axis intersected by the f-function, is greater than α. On the other hand, if (q,p) is observed in $NW\,(\alpha)$, u is smaller than α. Suppose (q,p) is observed in $NE\,(\alpha)$. Since the g-function is downward-sloping, v is greater than α, whereas if (q,p) is observed in $SW\,(\alpha)$, v is smaller than α. This relationship implies the following proposition.

Proposition 1 *Suppose equations (1). For any real number α,*

(i) $P((q,p)\in SE(\alpha))\leq P(u\geq\alpha)\leq 1-P((q,p)\in NW(\alpha))$

(ii) $P((q,p)\in NE(\alpha))\leq P(v\geq\alpha)\leq 1-P((q,p)\in SW(\alpha))$

These bounds are sharp.

Proof: See Appendix.

$P(u\geq\alpha)=1-F_u(\alpha)$ and $P(v\geq\alpha)=1-F_v\,(\alpha)$, where F_u and F_v are the cumulative distribution function of the disturbances u and v, respectively. Thus, proposition 1 can be written as:

For any real number α,

$$(i)\ P((q,p)\in NW(\alpha))\leq F_u(\alpha)\leq 1-P((q,p)\in SE(\alpha)) \tag{2}$$

$$(ii)\ P((q,p)\in SW(\alpha))\leq F_v\,(\alpha)\leq 1-P((q,p)\in NE(\alpha)) \tag{3}$$

These bounds are sharp.

Fixing α, the bounds on $F_u(\alpha)$ are estimated by using the above inequality (2) and the analogous sample probabilities $P((q,p)\in NW(\alpha))$ and $P((q,p)\in SE(\alpha))$. Similarly, the bounds on $F_u(\alpha)$ are estimated for any α in the set of real numbers. Consequently, the bounds on the function $F_u(\bullet)$ are estimated. Similarly, the bounds on the function $F_v\,(\bullet)$ are estimated by using the inequality shown in inequality (3) and the analogous sample probabilities $P((q,p) \in SW(\alpha))$ and $P((q,p) \in NE(\alpha))$, for any real number α.

The goal of our methodology is to estimate the medians of u and v, which are defined as $\overline{u}$ and $\overline{v}$, respectively. Since F_u must exist between the estimated bounds on F_u, the quantiles of F_u are restricted in the region of the quantiles of the estimates of the bounds on F_u. Specifically, $\overline{u}$ must exist between the medians of the estimated bounds on F_u.

Lemma 2 *(i) Define α_1 and α_2 as follows. When the number of the observations, which is defined as n, is even,*

$\alpha_1 = \frac{1}{2}\left\{\arg\inf_{a_1}\left[P((q,p) \in NW(a_1)) = 0.5\right] + \arg\sup_{a_1}\left[P((q,p) \in NW(a_1)) = 0.5\right]\right\}.$

When n is odd, $\alpha_1 = \arg\inf_{a_1}\left[P((q,p) \in NW(a_1)) = \delta\right]$, where $\delta = \min \frac{m}{n}$ such that $\frac{m}{n} > 0.5$, where $m = 1, 2, ..., n$.

When n is even,

$\alpha_2 = \frac{1}{2}\left\{\arg\inf_{a_2}\left[P((q,p) \in SE(a_2)) = 0.5\right] + \arg\sup_{a_2}\left[P((q,p) \in SE(a_2)) = 0.5\right]\right\}.$

When n is odd, $\alpha_2 = \arg\inf_{a_1}\left[P((q,p) \in SE(a_2)) = \delta\right]$

Then

$$\alpha_2 \leq \overline{u} \leq \alpha_1$$

These bounds are sharp.

(ii) Define β_1 and β_2 as follows. When n is even,

$\beta_1 = \frac{1}{2}\left\{\arg\inf_{b_1}\left[P((q,p) \in SW(b_1)) = 0.5\right] + \arg\sup_{b_1}\left[P((q,p) \in SW(b_1)) = 0.5\right]\right\}.$

When n is odd, $\beta_1 = \arg\inf_{b_1}\left[P((q,p) \in SW(b_1)) = \delta\right].$

When n is even,

$\beta_2 = \frac{1}{2}\left\{\arg\inf_{b_2}\left[P((q,p) \in NE(b_2)) = 0.5\right] + \arg\sup_{b_2}\left[P((q,p) \in NE(b_2)) = 0.5\right]\right\}.$

When n is odd, $\beta_2 = \arg\inf_{b_2}\left[P((q,p) \in NE(b_2)) = \delta\right]$

Then

$$\beta_2 \leq \overline{v} \leq \beta_1$$

These bounds are sharp.

Proof: See Appendix.

Introducing certain assumptions narrows the estimates of the bounds of the medians of the disturbances. The following two assumptions on the distributions of u and v are considered.

Assumption 1.

The distributions of u and v are symmetric around the medians of u and v respectively.

Assumption 2.

The distributions of $u-\overline{u}$ and $v-\overline{v}$ are defined as $\widetilde{F_u}$ and $\widetilde{F_v}$ respectively, where $\overline{u}$ and $\overline{v}$ are medians of u and v respectively. (1) $\widetilde{F_u}$ and $\widetilde{F_v}$, are known by an econometrician and (2) $\widetilde{F_u}$ and $\widetilde{F_v}$ are strictly increasing functions.

Lemma 3 *Assume assumption 1.*

(i) Define $\alpha_1(\gamma)$ and $\alpha_2(\gamma)$ as follows.

$\alpha_1(\gamma)=\frac{1}{2}\left\{\arg\inf_{a_1}\left[P((q,p)\in NW(a_1))=\gamma\right]+\arg\sup_{a_1}\left[P((q,p)\in NW(a_1))=\gamma\right]\right\}$ *for* $\gamma=\frac{m}{n}$ *and* $m=1,2,...,n$.

$\alpha_1(\gamma)=\arg\inf_{a_1}\left[P((q,p)\in NW(a_1))=\widehat{\gamma}\right]$, *where* $\widehat{\gamma}=\min\frac{m}{n}$ *such that* $\frac{m}{n}>\gamma$ *(where* $m=1,2,...,n$*), for* $\gamma\in\left\{[0,1]-\left\{\frac{m}{n}\right\}_{m=1}^{n}\right\}$.

$\alpha_2(\gamma)=\frac{1}{2}\left\{\arg\inf_{a_2}\left[1-P((q,p)\in SE(a_2))=\gamma\right]+\arg\sup_{a_2}\left[1-P((q,p)\in SE(a_2))=\gamma\right]\right\}$ *for* $\gamma=\frac{m}{n}$ *(where* $m=1,2,...,n$*).*

$\alpha_2(\gamma)=\arg\inf_{a_2}\left[1-P((q,p)\in SE(a_2))=\widehat{\gamma}\right]$, *where* $\widehat{\gamma}=\min\frac{m}{n}$ *such that* $\frac{m}{n}>\gamma$ *(where* $m=1,2,...,n$*), for* $\gamma\in\left\{[0,1]-\left\{\frac{m}{n}\right\}_{m=1}^{n}\right\}$.

Then

$$\max_{\gamma\in[0,1]}\left[\alpha_2(\gamma)+\alpha_2(1-\gamma)\right]/2\leq\overline{u}\leq\min_{\gamma\in[0,1]}\left[\alpha_1(\gamma)+\alpha_1(1-\gamma)\right]/2.$$

These bounds are sharp.

(ii) Define $\beta_1(\gamma)$ and $\beta_2(\gamma)$ as follows.

$\beta_1(\gamma)=\frac{1}{2}\left\{\arg\inf_{b_1}\left[P((q,p)\in SW(b_1))=\gamma\right]+\arg\sup_{b_1}\left[P((q,p)\in SW(b_1))=\gamma\right]\right\}$ *for* $\gamma=\frac{m}{n}$ *and* $m=1,2,...,n$.

$\beta_1(\gamma) = \arg\inf_{b_1}[P((q,p) \in SW(b_1)) = \widehat{\gamma}]$, *where* $\widehat{\gamma} = \min \frac{m}{n}$ *such that* $\frac{m}{n} > \gamma$ (*where* $m = 1, 2, ..., n$), *for* $\gamma \in \left\{[0,1] - \left\{\frac{m}{n}\right\}_{m=1}^{n}\right\}$.

$\beta_2(\gamma) = \frac{1}{2}\left\{\arg\inf_{b_2}[1 - P((q,p) \in NE(b_2)) = \gamma] + \arg\sup_{b_2}[1 - P((q,p) \in NE(b_2)) = \gamma]\right\}$ *for* $\gamma = \frac{m}{n}$ (*where* $m = 1, 2, ..., n$).

$\beta_2(\gamma) = \arg\inf_{b_2}[1 - P((q,p) \in NE(b_2)) = \widehat{\gamma}]$, *where* $\widehat{\gamma} = \min \frac{m}{n}$ *such that* $\frac{m}{n} > \gamma$ (*where* $m = 1, 2, ..., n$), *for* $\gamma \in \left\{[0,1] - \left\{\frac{m}{n}\right\}_{m=1}^{n}\right\}$.

Then

$$\max_{\gamma \in [0,1]}[\beta_2(\gamma) + \beta_2(1-\gamma)]/2 \le \overline{v} \le \min_{\gamma \in [0,1]}[\beta_1(\gamma) + \beta_1(1-\gamma)]/2$$

These bounds are sharp.

Proof: See Appendix.

Lemma 4 *Suppose that assumption 2 holds. Then*

$$\begin{aligned}
\max_{\alpha \in A_2}\left\{\alpha - \widetilde{F_u}^{-1}[1 - P((q,p) \in SE(\alpha))]\right\} &\le \overline{u} \le \min_{\alpha \in A_1}\left\{\alpha - \widetilde{F_u}^{-1}[P((q,p) \in NW(\alpha))]\right\} \\
\max_{\beta \in B_2}\left\{\beta - \widetilde{F_v}^{-1}[1 - P((q,p) \in NE(\beta))]\right\} &\le \overline{v} \le \min_{\beta \in B_1}\left\{\beta - \widetilde{F_v}^{-1}[P((q,p) \in SW(\beta))]\right\},
\end{aligned}$$

where $A_1 = \left\{\alpha \,\middle|\, \alpha = \alpha_1(\gamma) \text{ for } \gamma = \frac{m}{n} \text{ or } \gamma = \left(\frac{m-1}{n} + \frac{m}{n}\right)/2, \text{ where } m = 1, 2, ..., n\right\}$,

$A_2 = \left\{\alpha \,\middle|\, \alpha = \alpha_2(\gamma) \text{ for } \gamma = \frac{m}{n} \text{ or } \gamma = \left(\frac{m-1}{n} + \frac{m}{n}\right)/2, \text{ where } m = 1, 2, ..., n\right\}$,

$B_1 = \left\{\beta \,\middle|\, \beta = \beta_1(\gamma) \text{ for } \gamma = \frac{m}{n} \text{ or } \gamma = \left(\frac{m-1}{n} + \frac{m}{n}\right)/2, \text{ where } m = 1, 2, ..., n\right\}$,

and $B_2 = \left\{\beta \,\middle|\, \beta = \beta_2(\gamma) \text{ for } \gamma = \frac{m}{n} \text{ or } \gamma = \left(\frac{m-1}{n} + \frac{m}{n}\right)/2, \text{ where } m = 1, 2, ..., n\right\}$.

These bounds are sharp.

Proof: See Appendix.

The next step is to estimate the supply and demand shift variables. Suppose that the output and prices of production in each industry are determined via the following panel data model with fixed effects, which is an extension of equations (1).

$$\begin{cases} \widehat{q_{it}} = f_{it}(\widehat{p_{it}}) + \mu_t + \varepsilon_{it} \\ \widehat{q_{it}} = g_{it}(\widehat{p_{it}}) + \nu_t + \xi_{it} \end{cases}, \tag{4}$$

where $\widehat{q_{it}} = q_{it} - \overline{q_{it}}$ and $\widehat{p_{it}} = p_{it} - \overline{p_{it}}$. $(\overline{q_{it}}, \overline{p_{it}})$ is a normalization. The medians of ε_{it} and ξ_{it} for i are zero. $f_{it}(\ )$ and $g_{it}(\ )$ are strictly increasing and decreasing functions respectively. $f_{it}(0) = g_{it}(0) = 0$. i is the index of the industries / products and t is the time index. $(\widehat{p_{it}}, \widehat{q_{it}})$ are observations. Fixed (time) effects (μ_t, ν_t) are supply and demand shift variables respectively, that are unknown parameters to be estimated. ε_{it} and ξ_{it} represent disturbances with supply and demand functions respectively. q_{it} and p_{it} are the growth rates of output and prices of ith-industry at time t respectively. $\mu_t + \varepsilon_{it}$ and $\nu_t + \xi_{it}$ correspond respectively to u and v in equations (1) and thus μ_t and ν_t correspond to $\overline{u}$ and $\overline{v}$ respectively.

This model demonstrates that the growth rates of output and prices co-move across the industries due to the common supply and demand shift variables, μ_t and ν_t, systematically. On the other hand, their independent movement is caused by idiosyncratic supply and demand disturbances, ε_{it} and ξ_{it}. The supply and demand curves, $f_{it}(\ )$ and $g_{it}(\ )$, do not have to be specified and may be different across both industries and time.

I use Lemmas 2, 3 and 4 to estimate μ_t and ν_t. When using Lemmas 3 and 4, I assume that the distributions of ε_{it} and ξ_{it} for i are time-invariant. The procedure of estimation is as follows. First, we fix t (time index) and α. Second, we estimate the bounds on μ_t (which correspond to the bounds on $\overline{u}$ in Lemmas 2, 3 and 4) by replacing the probabilities indicating the bounds with the corresponding sample frequencies. For example, the estimate of $P\left((\widehat{q_{it}}, \widehat{p_{it}}) \in NW(\alpha)\right)$ equals the number of the samples of $(\widehat{q_{it}}, \widehat{p_{it}})$ located in the $NW(\alpha)$ region at time t divided by the total number of samples of $(\widehat{q_{it}}, \widehat{p_{it}})$ at time t. The estimates of the other probabilities, $P((\widehat{q_{it}}, \widehat{p_{it}}) \in SE(\alpha))$, $P((\widehat{q_{it}}, \widehat{p_{it}}) \in SW(\alpha))$ and $P((\widehat{q_{it}}, \widehat{p_{it}}) \in NE(\alpha))$ are similarly obtained. Third, we repeat the procedures outlined in the first and second steps for any real number $\alpha \in [-\infty, \infty]$ and then obtain the estimates of bounds on μ_t for given t. Then we repeat the procedure (the first, second and third steps) for any time t in the sample periods and then obtain the time series of the estimates of the bounds on μ_t. Similarly, we estimate the time series of the estimates of the bounds on ν_t.

How to choose the normalization point $(\overline{q_{it}}, \overline{p_{it}})$ depends on the economic problems to which this approach is applied. We take $(\overline{q_{it}}, \overline{p_{it}}) = (E(q_{it} \mid I_{t-1}), E(p_{it} \mid I_{t-1}))$ as a normalization where I_{t-1} is information available at $t-1$. Then, $\widehat{x_{it}} = x_{it} - E(x_{it} \mid I_{t-1})$ $(x = q, p)$ are innovations and considered unexpected changes of the variables. It should be noted that $E_t(\widehat{x_{it}}) = 0$ where $E_t(\widehat{x_{it}})$ is the mean of $\widehat{x_{it}}$ over time. If (1) $E_t\left(f_{it}\left(\widehat{p_{it}}\right)\right) = f_{it}\left(E_t\left(\widehat{p_{it}}\right)\right)$ and $E_t\left(g_{it}\left(\widehat{p_{it}}\right)\right) = g_{it}\left(E_t\left(\widehat{p_{it}}\right)\right)$, and (2) $E_t\left(y\right) = 0$ for $y = \mu_t, \nu_t, \varepsilon_{it}$ and ξ_{it}, then $f_{it}(0) = g_{it}(0) = 0$.

I apply two types of formations of expectations, $E(z_{it} \mid I_{t-1})$, in order to replace them with data.

(A): $E(z_{it} \mid I_{t-1}) = E_t\left(z_{it}\right)$, where E_t is the mean over t.

(B): $E(z_{it} \mid I_{t-1}) = z_{it-1}$.

When Lemma 4 is applied for estimation, I assume the distributions of ε_{it} and ξ_{it} to be normal distributions, where their means are zero and their variances are σ_ε^2 and σ_ξ^2, satisfying the followings respectively,

$$\max_\alpha \left\{\alpha - \Phi_\varepsilon^{-1}\left[1 - P((\widehat{q_{it}}, \widehat{p_{it}}) \in SE(\alpha))\right]\right\} \leq \min_\alpha \left\{\alpha - \Phi_\varepsilon^{-1}\left[P((\widehat{q_{it}}, \widehat{p_{it}}) \in NW(\alpha))\right]\right\}$$

and

$$\max_\alpha \left\{\alpha - \Phi_\xi^{-1}\left[1 - P((\widehat{q_{it}}, \widehat{p_{it}}) \in NE(\alpha))\right]\right\} \leq \min_\alpha \left\{\alpha - \Phi_\xi^{-1}\left[P((\widehat{q_{it}}, \widehat{p_{it}}) \in SW(\alpha))\right]\right\},$$

where $\Phi_l\left(x\right) = \left(1/\sigma_l\right)\phi\left(x/\sigma_l\right)$ $(l = \varepsilon, \xi)$.

3 The Estimation Results

This section employs the panel data of prices and output classified by industry-level to estimate macro demand and supply shocks in Japan, Korea, China, Taiwan, Hong Kong, Singapore, Malaysia, Indonesia and the Philippines[4]. The 3 digit industry-level data comes from INDSTAT3 database (Industrial Statistics Database at the 3 digit level of ISIC code (Rev.2)) in 2003 (CDROM version). q_{it} and p_{it} are the growth rates of the Index number of industrial production and wages of i-th industry at t-year in each country/area, respectively[5]. (i is the index of the category of personal consumption goods and t is the time index.) The data is yearly data and its sample period is from 1963 to 2000 for Japan, Korea and Singapore, from 1970 to 2000 for Indonesia, from 1973 to 2000 for Taiwan, from 1968 to 1997 for Malaysia, from 1963 to 1996 for the Philippines, from 1973 to 1996 for Hong Kong, and from 1977 to 1986 for China due to its availability[6].

The equations (4) are assumed to hold in each country and area. μ_t and ν_t represent macro supply and demand shocks respectively. (Hereafter, I use the term "(macro) shocks" instead of "shift variables".) ε_{it} and ξ_{it} represent idiosyncratic supply and demand shocks respectively. The econometric approach explained in section 2 is applied to estimate the sharp bounds on supply and demand shocks in each country/area.

Figures 2-5 show the estimates of the bounds on the macro supply and demand shocks. Figure 2 assumes that the distribution of the idiosyncratic disturbance is assumed to have a zero median and (A) is applied to formations of expectations. Figure 3 assumes normal distribution as the distribution of the disturbances and (A) as formations of expectations. Figure 4 assumes disturbances with a zero median and (B), whereas Figure 5 assumes normal distribu-

[4] Watanabe el al. (2003) used the distribution of price data classified by products in the countries in East Asia to measure supply shocks. They assumed that the relative price changes of some products to others are caused by supply shocks and investigate the cross-sectional skewness of price changes in Japan, the US, the UK, Korea, Hong Kong and Taiwan to measure their supply shocks.

[5] I assume markup pricing, and thus use wages as a proxy for the prices of products

[6] The case of Thailand is not studied because its data is not available before 1966, in 1972, 73, 78, 80, 81, 83, 85,87, 92 and after 1995.

tions of the disturbances and (B). The estimation results when the disturbances are assumed to be symmetric around zero are available from the author upon request.

Comparison of the estimated shocks among the countries and areas imply the following:

(1) The estimated supply shocks in Japan, Korea and Taiwan look parallel, except that those in Korea and Taiwan slumped around 1990, whereas those in Japan decreased in 1992,

(2) The estimated supply shocks in Malaysia and Indonesia look parallel. The supply shock in Singapore moved parallel with those in Malaysia and Indonesia until around 1990. After 1990 it moved in the opposite direction to these two countries and in a parallel direction to Japan, Korea and Taiwan,

(3) The estimated demand shocks among Japan, Korea and Taiwan do not look parallel until 1990. However, in the 1990s those of Japan, Korea, Taiwan, Hong Kong, Singapore and the Philippines all declined, and

(4) The estimated demand shocks in Malaysia and Indonesia fluctuated parallel. The estimated demand shocks in these countries and Hong Kong moved parallel until 1990; however, after 1990 they moved in the opposite direction.

Kawai and Okumura (1996) estimated the supply and demand shocks in the countries and areas in East Asia using the structural VAR, which assumes that demand shocks do not affect output in the long run. Subsequently, they investigate the correlation of the estimated shocks among the countries/areas to study the macroeconomic interdependence in East Asia. They found:

(1) the estimated supply shocks in Japan and Taiwan have a positive correlation,

(2) the estimated supply shocks in Singapore, Malaysia, Indonesia and Thailand have a strong correlation,

(3) the estimated supply shocks in Taiwan, Hong Kong, Malaysia and In-

donesia are positively correlated, and

(4) the estimated demand shocks in Malaysia, Indonesia, the Philippines, Thailand and Hong Kong have a strong positive correlation.

The estimation results of this paper and Kawai and Okumura (1996) lead to a similar interpretation about the relationship of economic interdependence in East Asia, although these two approaches (the assumptions for identifications) are different. The similarities and differences in the results of this and their paper are:

(1) The supply factors are found to be mutually dependent among Japan, Korea and Taiwan in both pieces of research,

(2) Both supply and demand factors are strong and mutually dependent between Malaysia and Indonesia of ASEAN in both pieces of research,

(3) The interdependence of the shocks in Malaysia and Indonesia and those in Singapore and Hong Kong were found until 1990; it disappeared, however, after 1990. Kawai and Okumura (1996) found their strong interdependence using data from 1970 to 1993. These results thus imply that this relationship changed around 1990, and

(4) This paper shows that demand factors have declined in Japan, Korea, Taiwan, Hong Kong and the Philippines since 1990 as a result of recession and deflation. It also implies the possibility of structural change in macroeconomic interdependence in East Asia around 1990.

4 Conclusion

This paper estimates macro demand and supply shocks causing business fluctuations in Japan, Korea, China, Taiwan, Hong Kong, Singapore, Malaysia, Indonesia and the Philippines. It uses the industry-level data of wages and index of industrial production and the nonparametric econometric model developed by Okumura (2003), which enables us to estimate supply and demand shift variables when only the intersections of supply and demand curves are observable. Subsequently, it investigates the correlation of the estimated shocks among the countries and areas to clarify their macroeconomic interdependence. Found are: (1) the strong correlations of supply shocks among Japan, Korea and Taiwan, (2) the strong correlations of demand and supply shocks between Malaysia and Indonesia, and (3) the possibility of structural changes in interaction in East Asia around 1990.

There are some problematic points to this research that require further investigation. First, due to the lack of availability of data, it insufficiently studied the cases of Thailand and China. Since data in Hong Kong, Malaysia and the Philippines after 1997, when the currency crisis occurred, is not available, the independency concerning these countries/areas could not be studied. Second, as price variables, wholesale or consumer price indexes would be better than wages. Third, the econometric model can estimate the bounds on the shocks; it cannot, however, point-estimate the shocks. Thus, to investigate the correlation of the estimated shocks, I could not use the statistical tests such as correlation coefficients. These topics are, however, left for future research.

5 Appendix

Proof of Proposition 1.

Since f is monotone increasing in p, for any real number α,

$$\begin{cases} (q,p) \in SE(\alpha) \Rightarrow u \geq \alpha \\ (q,p) \in NW(\alpha) \Rightarrow u \leq \alpha. \end{cases}$$

Thus

$$P\left((q,p) \in SE(\alpha)\right) \leq P(u \geq \alpha) \leq 1 - P\left((q,p) \in NW(\alpha)\right)$$

These bounds are sharp, since the empirical evidence and prior information are consistent with the hypothesis $\{(q,p) \in SE(\alpha)\} \Leftrightarrow \{u \geq \alpha\}$ and also with the hypothesis $\{(q,p) \in NW(\alpha)\} \Leftrightarrow \{u \leq \alpha\}$.

Since g is monotone decreasing in p, for any real number α

$$\begin{cases} (q,p) \in NE(\alpha) \Rightarrow v \geq \alpha \\ (q,p) \in SW(\alpha) \Rightarrow v \leq \alpha. \end{cases}$$

Thus

$$P((q,p) \in NE(\alpha)) \leq P(v \geq \alpha) \leq 1 - P((q,p) \in SW(\alpha))$$

These bounds are sharp, since the empirical evidence and prior information are consistent with the hypothesis $\{(q,p) \in NE(\alpha)\} \Leftrightarrow \{v \geq \alpha\}$ and also with the hypothesis $\{(q,p) \in SW(\alpha)\} \Leftrightarrow \{v \leq \alpha\}$. Q.E.D.

Proof of Lemma 2.

Equation (2) and the definition of α_1 imply that

$$F_u(\overline{u}) = 0.5 = P((q,p) \in NW(\alpha_1)) \leq F_u(\alpha_1).$$

When $F_u(\alpha_1) > 0.5$, since F_u is an increasing function, $\overline{u} < \alpha_1$.

When $F_u(\alpha_1) = 0.5$, since $P((q,p) \in NW(\alpha)) \leq F_u(\alpha)$ for $\forall\alpha$ and $P((q,p) \in NW(\alpha))$ is increasing in α,

$$\begin{aligned} \arg\sup_{\alpha} \{P((q,p) \in NW(\alpha)) = 0.5\} &\geq \arg\sup_{\alpha} \{F_u(\alpha) = 0.5\}, \text{ and} \\ \arg\inf_{\alpha} \{P((q,p) \in NW(\alpha)) = 0.5\} &\geq \arg\inf_{\alpha} \{F_u(\alpha) = 0.5\}. \end{aligned}$$

Thus, $\overline{u} \leq \alpha_1$.

Hence, $\overline{u} \leq \alpha_1$.

Equation (2) and the definition of α_2 imply that

$$F_u(\alpha_2) \leq 1 - P\left((q,p) \in SE\left(\alpha_2\right)\right) = 0.5 = F_u(\overline{u}).$$

When $F_u(\alpha_2) < 0.5$, since F_u is an increasing function, $\alpha_2 < \overline{u}$.

When $F_u(\alpha_2) = 0.5$, since $F_u(\alpha) \leq 1 - P\left((q,p) \in SE\left(\alpha\right)\right)$ for $\forall\alpha$ and $1 - P\left((q,p) \in SE\left(\alpha\right)\right)$ is increasing in α,

$$\begin{aligned}
\arg\sup_{\alpha}\left\{P\left((q,p) \in SE\left(\alpha\right)\right) = 0.5\right\} &\leq \arg\sup_{\alpha}\left\{F_u(\alpha) = 0.5\right\}, \text{ and} \\
\arg\inf_{\alpha}\left\{P\left((q,p) \in SE\left(\alpha\right)\right) = 0.5\right\} &\leq \arg\inf_{\alpha}\left\{F_u(\alpha) = 0.5\right\}.
\end{aligned}$$

Thus, $\alpha_2 \leq \overline{u}$.

Hence, $\alpha_2 \leq \overline{u}$.

Hence,

$$\alpha_2 \leq \overline{u} \leq \alpha_1.$$

These bounds are sharp, since the empirical evidence and prior information are consistent with the hypothesis $\overline{u} = \alpha_1$ and also with the hypothesis $\overline{u} = \alpha_2$. The hypothesis $\overline{u} = \alpha_1$ occurs when all supply curves traversing the observations with nonnegative p are vertical and all supply curves traversing the observation with nonpositive p have nearly zero but positive slope. The hypothesis $\overline{u} = \alpha_2$ occurs when all supply curves traversing the observations with nonpositive p are vertical and all supply curves traversing the observation with nonnegative p have nearly zero but positive slope.

Similarly,

$$\beta_2 \leq \overline{v} \leq \beta_1$$

These bounds are sharp.

Q.E.D.

Proof of Lemma 3.

Define the γ quantile of F_u as m^u_γ.

Equation (2) and the definition of $\alpha_1(\gamma)$ imply that

$$F_u(m^u_\gamma) = \gamma = P\left((q,p) \in NW\left(\alpha_1(\gamma)\right)\right) \leq F_u(\alpha_1(\gamma)).$$

When $F_u(\alpha_1(\gamma)) > \gamma$, since F_u is an increasing function, $m^u_\gamma < \alpha_1(\gamma)$.

When $F_u(\alpha_1(\gamma)) = \gamma$, since $P\left((q,p) \in NW(\alpha)\right) \leq F_u(\alpha)$ for $\forall\alpha$ and $P\left((q,p) \in NW(\alpha)\right)$ is increasing in α,

$$\begin{aligned}
\arg\sup_{\alpha_1}\left\{P\left((q,p) \in NW(\alpha_1)\right) = \gamma\right\} &\geq \arg\sup_{\alpha}\left\{F_u(\alpha) = \gamma\right\}, \text{ and} \\
\arg\inf_{\alpha_1}\left\{P\left((q,p) \in NW(\alpha_1)\right) = \gamma\right\} &\geq \arg\inf_{\alpha}\left\{F_u(\alpha) = \gamma\right\}.
\end{aligned}$$

Thus, $m^u_\gamma \leq \alpha_1(\gamma)$.

Hence, $m^u_\gamma \leq \alpha_1(\gamma)$.

Equation (2) and the definition of $\alpha_2(\gamma)$ imply that

$$F_u(\alpha_2(\gamma)) \leq 1 - P\left((q,p) \in SE\left(\alpha_2(\gamma)\right)\right) = \gamma = F_u(m^u_\gamma).$$

When $F_u(\alpha_2(\gamma)) < \gamma$, since F_u is an increasing function, $\alpha_2(\gamma) < m^u_\gamma$.

When $F_u(\alpha_2(\gamma)) = \gamma$, since $F_u(\alpha) \leq 1 - P\left((q,p) \in SE(\alpha)\right)$for $\forall\alpha$ and $1 - P\left((q,p) \in SE(\alpha)\right)$ is increasing in α,

$$\begin{aligned}
\arg\sup_{\alpha_2}\left\{1 - P\left((q,p) \in SE(\alpha_2)\right) = \gamma\right\} &\leq \arg\sup_{\alpha}\left\{F_u(\alpha) = \gamma\right\}, \text{ and} \\
\arg\inf_{\alpha_2}\left\{1 - P\left((q,p) \in SE(\alpha_2)\right) = \gamma\right\} &\leq \arg\inf_{\alpha}\left\{F_u(\alpha) = \gamma\right\}.
\end{aligned}$$

Thus, $\alpha_2(\gamma) \leq m^u_\gamma$.

Hence, $\alpha_2(\gamma) \leq m^u_\gamma$.

Hence

$$\alpha_2(\gamma) \leq m^u_\gamma \leq \alpha_1(\gamma).$$

Subtracting $\overline{u}$ from both sides

$$\alpha_2(\gamma) - \overline{u} \leq m^u_\gamma - \overline{u} \leq \alpha_1(\gamma) - \overline{u}. \tag{5}$$

Similarly for the $(1-\gamma)$ quantile of F_u

$$\alpha_2(1-\gamma) \leq m^u_{1-\gamma} \leq \alpha_1(1-\gamma).$$

Thus

$$\alpha_2(1-\gamma) - \overline{u} \leq m^u_{1-\gamma} - \overline{u} \leq \alpha_1(1-\gamma) - \overline{u}. \tag{6}$$

Since the symmetry of the distribution of u around $\overline{u}$ implies $m^u_\gamma - \overline{u} = -\left(m^u_{1-\gamma} - \overline{u}\right)$, equations (5) and (6) imply that

$$[\alpha_2(\gamma) + \alpha_2(1-\gamma)]/2 \leq \overline{u} \leq [\alpha_1(\gamma) + \alpha_1(1-\gamma)]/2. \tag{7}$$

Since inequality (7) holds for any $\gamma \in [0,1]$,

$$\max_{\gamma\in[0,1]} [\alpha_2(\gamma) + \alpha_2(1-\gamma)]/2 \leq \overline{u} \leq \min_{\gamma\in[0,1]} [\alpha_1(\gamma) + \alpha_1(1-\gamma)]/2.$$

These bounds are sharp, since the empirical evidence and prior information are consistent with the hypothesis $\overline{u} = \max_{\gamma\in[0,1]} [\alpha_2(\gamma) + \alpha_2(1-\gamma)]/2$ and also with the hypothesis $\overline{u} = \min_{\gamma\in[0,1]} [\alpha_1(\gamma) + \alpha_1(1-\gamma)]/2$.

$\overline{u} = \max_{\gamma\in[0,1]} [\alpha_2(\gamma) + \alpha_2(1-\gamma)]/2$ is realized when u_is are distributed in the following way. Define $q^l_{(i)}$ as the order statistics of $\{q_j\}$ which have nonpositive p and $u^l_{(i)}$ as the disturbances corresponding to $q^l_{(i)}$ for $i = 1, 2, ..., n - k_1$, where k_1 is the number of the observations with positive p. (Hereafter, i is the natural number.) Define $\overline{u_L} = \max_{\gamma \in [0,1]} \left[\alpha_2(\gamma) + \alpha_2(1-\gamma)\right]/2$. Consider the case that p corresponding to $q^l_{(i)}$ for $i \leq \frac{n}{2} - k_1$ is not zero. Suppose that the supply curves traversing the observations $q^l_{(i)}$ for $\frac{n}{2} - k_1 + 1 \leq i \leq n - 2k_1$

are vertical, and thus $u^l_{(i)} = q^l_{(i)}$. $u^l_{(i)}$ for $1 \leq i \leq \frac{n}{2} - k_1$ and $u^l_{(i)} = q^l_{(i)}$ for $\frac{n}{2} - k_1 + 1 \leq i \leq n - 2k_1$ can be distributed symmetrically around $\overline{u_L}$ in the following way. Let us place $u^l_{(i)}$ for $1 \leq i \leq \frac{n}{2} - k_1$ in the way that $\overline{u_L} - u^l_{(i)} = u^l_{(n-2k_1+1-i)} - \overline{u_L}$ for $1 \leq i \leq \frac{n}{2} - k_1$. We should notice that $u^l_{(n-2k_1+1-i)} = q^l_{(n-2k_1+1-i)}$ for $1 \leq i \leq \frac{n}{2} - k_1$. It needs to be shown that the supply curves traversing $u^l_{(i)}$ and the observations with $q^l_{(i)}$ for $1 \leq i \leq \frac{n}{2} - k_1$ have positive slopes. Since $\alpha_2\left(\left(\frac{j}{n} + \frac{j+1}{n}\right)/2\right) = q^l_{(j+1-k_1)}$ for $1 \leq j \leq n$ where j is the natural number, and $\overline{u_L} \geq \left[\alpha_2(\gamma) + \alpha_2(1-\gamma)\right]/2$ for $\forall \gamma \in [0,1]$,

$$\begin{aligned}&\left[\alpha_2\left(\left(\tfrac{j}{n} + \tfrac{j+1}{n}\right)/2\right) + \alpha_2\left(1 - \left(\tfrac{j}{n} + \tfrac{j+1}{n}\right)/2\right)\right]/2 - \overline{u_L}\\ &= \left[\left(q^l_{(j+1-k_1)} - \overline{u_L}\right) + \left(u^l_{(n-j-k_1)} - \overline{u_L}\right) + \left(q^l_{(n-j-k_1)} - u^l_{(n-j-k_1)}\right)\right]/2\\ &\leq 0.\end{aligned}$$

Since $q^l_{(j+1-k_1)} - \overline{u_L} = \overline{u_L} - u^l_{(n-j-k_1)}$ for $n - 1 - k_1 \leq j \leq \frac{n}{2}$, $q^l_{(n-j-k_1)} \leq u^l_{(n-j-k_1)}$ and thus, $q^l_{(i)} \leq u^l_{(i)}$ for $1 \leq i \leq \frac{n}{2} - k_1$. Thus, the supply curves traversing $u^l_{(i)}$ and the observations with $q^l_{(i)}$ have positive slopes. When the number of the observations is odd, place $u^l_{\left(\frac{n+1}{2} - k_1\right)}$ so that $u^l_{\left(\frac{n+1}{2} - k_1\right)} = \overline{u_L}$. Then, since $q^l_{\left(\frac{n+1}{2} - k_1\right)} = \alpha_2(0.5) \leq \overline{u_L}$, the supply curves traversing $u^l_{\left(\frac{n+1}{2} - k_1\right)}$ and the observations with $q^l_{\left(\frac{n+1}{2} - k_1\right)}$ have positive slopes.

Next, $u^l_{(i)}$ for $\frac{n}{2} - k_1 < i \leq n$ and u_js which correspond to the observations with nonnegative p can be distributed symmetrically around $\overline{u_L}$ and the supply curves traversing the observations corresponding to these disturbances have positive slopes.

When p corresponding to $q^l_{(i)}$ for some $i \leq \frac{n}{2} - k_1$ are zero, let us place $u^l_{(n-2k_1+1-i)}$ in the way that $u^l_{(n-2k_1+1-i)} - \overline{u_L} = \overline{u_L} - u^l_{(i)}$ for such i. Similarly, it is proved that $u^l_{(n-2k_1+1-i)} \geq q^l_{(n-2k_1+1-i)}$ for such i. Thus, the supply curves traversing $u^l_{(n-2k_1+1-i)}$ and the observations with $q^l_{(n-2k_1+1-i)}$ for such i have positive slopes. Consequently, such distribution of u_i implies $\overline{u_L} = \max_{\gamma\in[0,1]}\left[\alpha_2(\gamma)+\alpha_2(1-\gamma)\right]/2$.

$\overline{u} = \min_{\gamma\in[0,1]}\left[\alpha_1(\gamma)+\alpha_1(1-\gamma)\right]/2$ is realized when u_is are distributed in the following way. Define $q^h_{(i)}$ as the order statistics of $\{q_j\}$ which have nonnegative p and $u^h_{(i)}$ as the disturbances corresponding to $q^h_{(i)}$ for $i=1,2,...,n-k_2$, where k_2 is the number of the observations with negative p. Define $\overline{u_H} = \min_{\gamma\in[0,1]}\left[\alpha_1(\gamma)+\alpha_1(1-\gamma)\right]/2$. Suppose that the supply curves traversing the observations $q^h_{(i)}$ for $k_2+1\le i\le \frac{n}{2}$ are vertical, and thus $u^h_{(i)} = q^h_{(i)}$. $u^h_{(i)}$ for $\frac{n}{2}+1\le i\le n-k_2$ and $u^h_{(i)} = q^h_{(i)}$ for $k_2+1\le i\le\frac{n}{2}$ can be distributed symmetrically around $\overline{u_H}$ in the following way. Let us place $u^h_{(i)}$ for $\frac{n}{2}+1\le i\le n-k_2$ in the way that $u^h_{(i)}-\overline{u_H} = \overline{u_H}-u^h_{(n+1-i)}$ for $\frac{n}{2}+1\le i\le n-k_2$. We should notice that $u^h_{(n+1-i)} = q^h_{(n+1-i)}$ for $\frac{n}{2}+1\le i\le n-k_2$. It needs to be shown that the supply curves traversing $u^h_{(i)}$ and the observations with $q^h_{(i)}$ for $\frac{n}{2}+1\le i\le n-k_2$ have positive slopes. Since $\alpha_1\left(\left(\frac{j-1}{n}+\frac{j}{n}\right)/2\right) = q^h_{(j)}$ for $1\le j\le n-k_2$ and $\overline{u_H}\le\left[\alpha_1(\gamma)+\alpha_1(1-\gamma)\right]/2$ for $\forall\gamma\in[0,1]$,

$$\begin{aligned}&\left[\alpha_1\left(\left(\tfrac{j-1}{n}+\tfrac{j}{n}\right)/2\right)+\alpha_1\left(1-\left(\tfrac{j-1}{n}+\tfrac{j}{n}\right)/2\right)\right]/2-\overline{u_H}\\ &=\left[\left(q^h_{(j)}-\overline{u_H}\right)+\left(u^h_{(n-j+1)}-\overline{u_H}\right)+\left(q^h_{(n+1-j)}-u^h_{(n+1-j)}\right)\right]/2\ge 0.\end{aligned}$$

Since $\overline{u_H}-q^h_{(j)} = u^h_{(n+1-j)}-\overline{u_H}$ for $k_2+1\le j\le\frac{n}{2}$, $q^h_{(n+1-j)}\ge u^h_{(n+1-j)}$ and thus, $q^h_{(i)}\le u^h_{(i)}$ for $\frac{n}{2}+1\le i\le n-k_2$. Thus, the supply curves traversing $u^h_{(i)}$ and the observations with $q^h_{(i)}$ have positive slopes. When the number of the observations is odd, place $u^h_{\left(\frac{n+1}{2}\right)}$ so that $u^h_{\left(\frac{n+1}{2}\right)} = \overline{u_H}$. Then, since $q^h_{\left(\frac{n+1}{2}\right)} = \alpha_1(0.5)\ge\overline{u_H}$, the supply curves traversing $u^h_{\left(\frac{n+1}{2}\right)}$ and the observations with $q^h_{\left(\frac{n+1}{2}\right)}$ have positive slopes.

Next, $u^h_{(i)}$ for $i\le k_2$ and u_js which correspond to the observations with nonpositive p can be distributed symmetrically around $\overline{u_H}$ and the supply curves traversing the observations corresponding to these disturbances have positive slopes. When p corresponding to $q^h_{(i)}$ for some $\frac{n}{2}+1 \leq i \leq n-k_2$ are zero, let us place $u^h_{(n+1-i)}$ in the way that $\overline{u_H} - u^h_{(n+1-i)} = u^h_{(i)} - \overline{u_H}$ for such i. Similarly, it is proved that $u^h_{(n+1-i)} \geq q^h_{(n+1-i)}$ for such i. Thus, the supply curves traversing $u^h_{(n+1-i)}$ and the observations with $q^h_{(n+1-i)}$ for such i have positive slopes. Consequently, such distribution of u_i implies $\overline{u} = \min_{\gamma\in[0,1]} \left[\alpha_1(\gamma) + \alpha_1(1-\gamma)\right]/2$.

Similarly for $\overline{v}$, since $P\left((q,p) \in SW(\alpha)\right)$ and $1 - P\left((q,p) \in NE(\alpha)\right)$ are increasing in α, it is proved that

$$\max_{\gamma\in[0,1]} \left[\beta_2(\gamma) + \beta_2(1-\gamma)\right]/2 \leq \overline{v} \leq \min_{\gamma\in[0,1]} \left[\beta_1(\gamma) + \beta_1(1-\gamma)\right]/2.$$

These bounds are sharp, since the empirical evidence and prior information are consistent with the hypothesis $\overline{v} = \max_{\gamma\in[0,1]} \left[\beta_2(\gamma) + \beta_2(1-\gamma)\right]/2$ and also with the hypothesis $\overline{v} = \min_{\gamma\in[0,1]} \left[\beta_1(\gamma) + \beta_1(1-\gamma)\right]/2$. The proof is similar to that for $\overline{u}$ and is available from the author upon request.

Q.E.D.

Proof of Lemma 4.

Since $F_u(\alpha) = \widetilde{F_u}(\alpha - \overline{u})$, equation (2) implies that

$$P\left((q,p) \in NW(\alpha)\right) \leq \widetilde{F_u}(\alpha - \overline{u}) \leq 1 - P\left((q,p) \in SE(\alpha)\right).$$

Since $\widetilde{F_u}$ is known and $\widetilde{F_u}$ is strictly increasing, by taking the inverse of $\widetilde{F_u}$

$$\widetilde{F_u}^{-1}\left[P\left((q,p) \in NW(\alpha)\right)\right] \leq \alpha - \overline{u} \leq \widetilde{F_u}^{-1}\left[1 - P\left((q,p) \in SE(\alpha)\right)\right].$$

Thus

$$\alpha - \widetilde{F_u}^{-1}\left[1 - P\left((q,p) \in SE(\alpha)\right)\right] \leq \overline{u} \leq \alpha - \widetilde{F_u}^{-1}\left[P\left((q,p) \in NW(\alpha)\right)\right].$$

Since it holds for any real number α,

$$\max_{\alpha\in A_2}\left\{\alpha-\widetilde{F_u}^{-1}\left[1-P\left((q,p)\in SE\left(\alpha\right)\right)\right]\right\}\leq\overline{u}\leq\min_{\alpha\in A_1}\left\{\alpha-\widetilde{F_u}^{-1}\left[P\left((q,p)\in NW\left(\alpha\right)\right)\right]\right\}.$$

These bounds are sharp, since the empirical evidence and prior information are consistent with the hypothesis $\overline{u}=\max_{\alpha\in A_2}\left\{\alpha-\widetilde{F_u}^{-1}\left[1-P\left((q,p)\in SE\left(\alpha\right)\right)\right]\right\}$ and also with the hypothesis $\overline{u}=\min_{\alpha\in A_1}\left\{\alpha-\widetilde{F_u}^{-1}\left[P\left((q,p)\in NW\left(\alpha\right)\right)\right]\right\}$. $\overline{u_L}=\max_{\alpha\in A_2}\left\{\alpha-\widetilde{F_u}^{-1}\left[1-P\left((q,p)\in SE\left(\alpha\right)\right)\right]\right\}$ is attained when u_is are distributed in the following way. Define $F_{H,u}(\alpha)$ as $F_u(\alpha)$ satisfying $F_u(\alpha_L)=1-P\left((q,p)\in SE\left(\alpha_L\right)\right)$, where $\alpha_L=\arg\max_{\alpha\in A_2}\left\{\alpha-\widetilde{F_u}^{-1}\left[1-P\left((q,p)\in SE\left(\alpha\right)\right)\right]\right\}$, i.e., $F_{H,u}$ is the upper bound of F_u. Suppose $u^l_{(i)}=F^{-1}_{H,u}\left(\frac{(k_1+i-1)+(k_1+i)}{2n}\right)$ for $i=1,2,...,n-k_1$, where $u^l_{(i)},q^l_{(i)}$ and k_1 are defined in the same way as the proof of Lemma 3. Suppose $u^l_j=F^{-1}_{H,u}\left(\frac{(j-1)+j}{2n}\right)$ for $j=1,2,...,k_1$, where u^l_js are the disturbances corresponding to the observations with nonnegative p. Then, u^l_is are consistent with the quantiles of $F_{H,u}$, and thus, $\overline{u_L}$ is attained. It needs to be shown that the supply curves traversing $u^l_{(i)}$ and the observations with $q^l_{(i)}$ for $i=1,2,...,n-k_1$ have positive slopes. By the definition of $\overline{u_L}$, $\overline{u_L}\geq\alpha_2\left(\gamma\right)-\widetilde{F_u}^{-1}\left[1-P\left((q,p)\in SE\left(\alpha_2\left(\gamma\right)\right)\right)\right]$ for $\gamma=\left(\frac{m-1}{n}+\frac{m}{n}\right)/2\ \ (m=k_1+1,...,n)$. Since $q^l_{(i)}=\alpha_2\left(\frac{(k_1+i-1)+(k_1+i)}{2n}\right)$ for $i=1,...,n-k_1$ and $\widetilde{F_u}^{-1}\left(\gamma\right)=F^{-1}_{H,u}\left(\gamma\right)-\overline{u_L}$, $\alpha_2\left(\frac{(k_1+i-1)+(k_1+i)}{2n}\right)-\widetilde{F_u}^{-1}\left[1-P\left((q,p)\in SE\left(\alpha_2\left(\frac{(k_1+i-1)+(k_1+i)}{2n}\right)\right)\right)\right]$ $=q^l_{(i)}-\widetilde{F_u}^{-1}\left(\frac{(k_1+i-1)+(k_1+i)}{2n}\right)=q^l_{(i)}-\left[F^{-1}_{H,u}\left(\frac{(k_1+i-1)+(k_1+i)}{2n}\right)-\overline{u_L}\right]=q^l_{(i)}-u^l_{(i)}+\overline{u_L}\leq\overline{u_L}$.

Hence, $q^l_{(i)}\leq u^l_{(i)}$.

Thus, the supply curves traversing $u^l_{(i)}$ and the observations with $q^l_{(i)}$ for $i=1,2,...,n-k_1$ have positive slopes.

$\overline{u_H}=\min_{\alpha\in A_1}\left\{\alpha-\widetilde{F_u}^{-1}\left[P\left((q,p)\in NW\left(\alpha\right)\right)\right]\right\}$ is attained when u_is are distributed in the following way. Define $F_{L,u}(\alpha)$ as $F_u(\alpha)$ satisfying $F_u(\alpha_H)=P\left((q,p)\in NW\left(\alpha_H\right)\right)$, where $\alpha_H=\arg\min_{\alpha\in A_1}\left\{\alpha-\widetilde{F_u}^{-1}\left[P\left((q,p)\in NW\left(\alpha\right)\right)\right]\right\}$, i.e., $F_{L,u}$ is the lower bound of F_u. Suppose $u^h_{(i)}=F^{-1}_{L,u}\left(\frac{(i-1)+i}{2n}\right)$ for $i=$

$1, 2, ..., n - k_2$, where $u^h_{(i)}, q^h_{(i)}$ and k_2 are defined in the same way as the proof of Lemma 3. Suppose $u^h_j = F^{-1}_{L,u}\left(\frac{(j-1)+j}{2n}\right)$ for $j = n - k_2 + 1, ..., n$, where u^h_js are the disturbances corresponding to the observations with nonpositive p. Then, u^h_is are consistent with the quantiles of $F_{L,u}$, and thus, $\overline{u_H}$ is attained. It needs to be shown that the supply curves traversing $u^h_{(i)}$ and the observations with $q^h_{(i)}$ for $i = 1, 2, ..., n - k_2$ have positive slopes. By the definition of $\overline{u_H}$, $\overline{u_H} \leq \alpha_1(\gamma) - \widetilde{F_u}^{-1}[P((q,p) \in NW(\alpha_1(\gamma)))]$ for $\gamma = \left(\frac{m-1}{n} + \frac{m}{n}\right)/2 \quad (m = 1, ..., n - k_2)$. Since $q^h_{(i)} = \alpha_1\left(\frac{(i-1)+i}{2n}\right)$ for $i = 1, 2, ..., n - k_2$ and $\widetilde{F_u}^{-1}(\gamma) = F^{-1}_{L,u}(\gamma) - \overline{u_H}$, $\alpha_1\left(\frac{(i-1)+i}{2n}\right) - \widetilde{F_u}^{-1}\left[P\left((q,p) \in NW\left(\alpha_1\left(\frac{(i-1)+i}{2n}\right)\right)\right)\right] = q^h_{(i)} - \widetilde{F_u}^{-1}\left(\frac{(i-1)+i}{2n}\right) = q^h_{(i)} - \left[F^{-1}_{L,u}\left(\frac{(i-1)+i}{2n}\right) - \overline{u_H}\right] = q^h_{(i)} - u^h_{(i)} + \overline{u_H} \geq \overline{u_H}$.

Hence, $q^h_{(i)} \geq u^h_{(i)}$.

Thus, the supply curves traversing $u^h_{(i)}$ and the observations with $q^h_{(i)}$ for $i = 1, 2, ..., n - k_2$ have positive slopes.

Similarly, since $F_v(\alpha) = \widetilde{F_v}(\alpha - \overline{u})$ and $\widetilde{F_v}$ is known and $\widetilde{F_v}$ is strictly increasing,

$$\max_{\alpha \in B_2}\left\{\alpha - \widetilde{F_v}^{-1}[1 - P((q,p) \in NE(\alpha))]\right\} \leq \overline{v} \leq \min_{\alpha \in B_1}\left\{\alpha - \widetilde{F_v}^{-1}[P((q,p) \in SW(\alpha))]\right\}.$$

These bounds are sharp.

Q.E.D.

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Figure 1

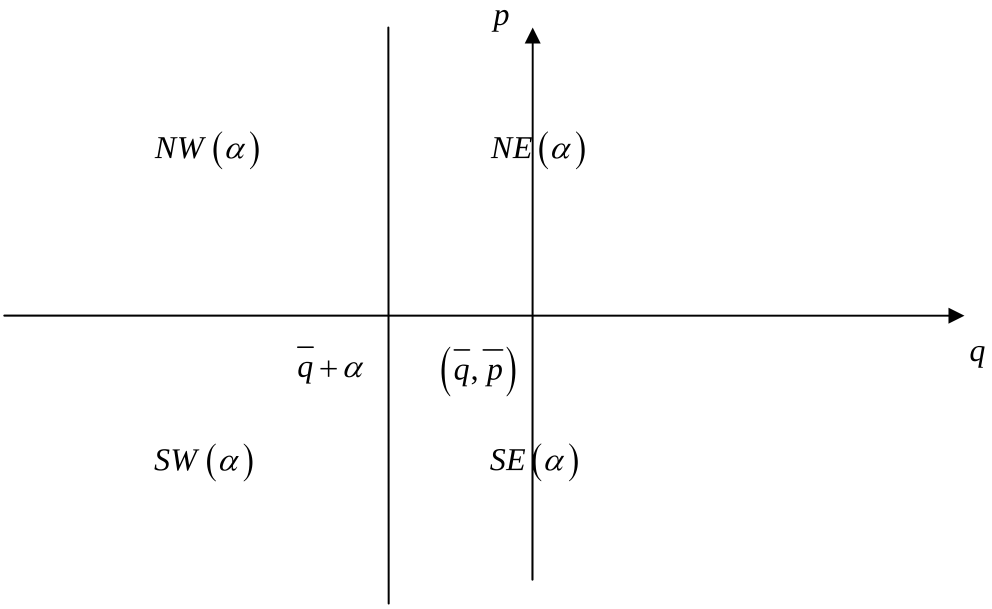


Figure 2. The estimates of the bounds on macro supply and demand shocks: μ_t and ν_t (the medians of ε_t, ξ_t are assumed 0 and the means of the variables over time are taken as a normalization .)

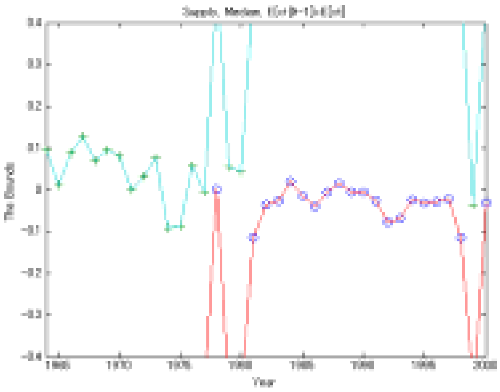
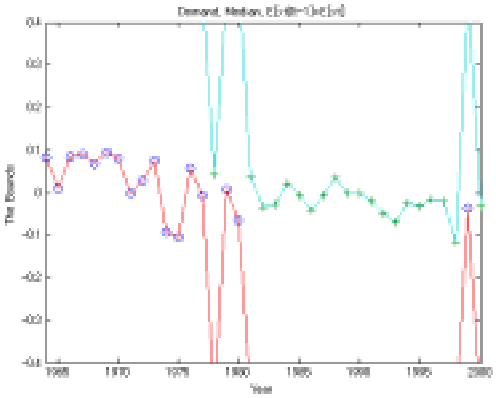
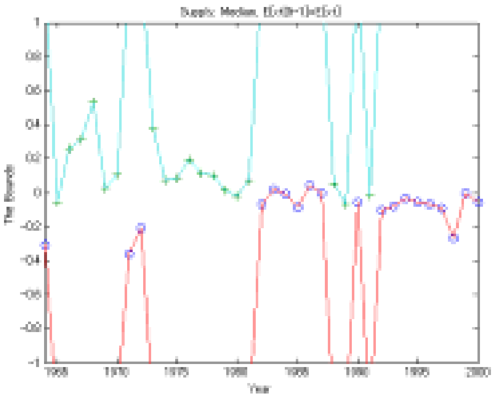
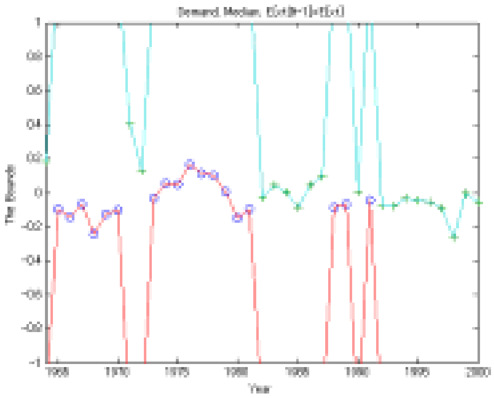
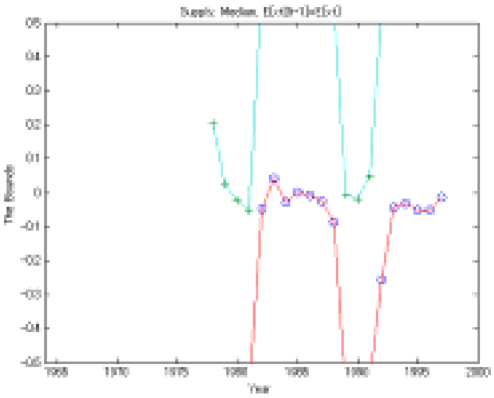
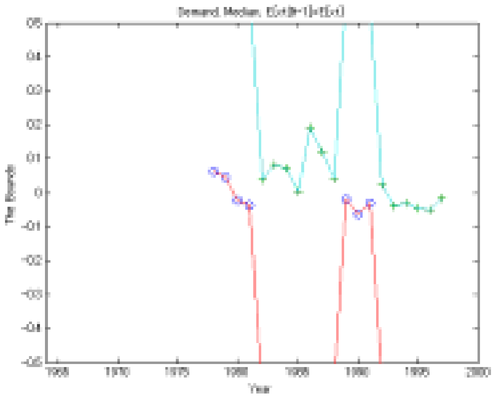
	Macro supply shocks μ_t	Macro demand shocks ν_t
Japan		
Korea		
Taiwan		

Figure 2 continued

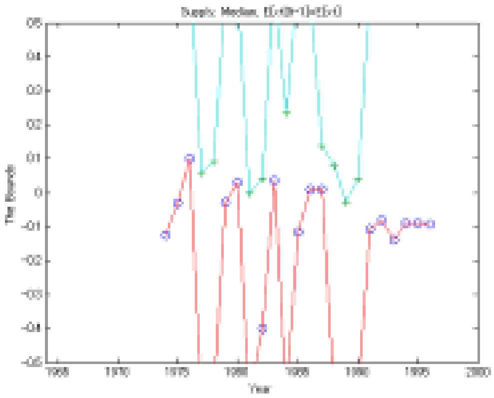
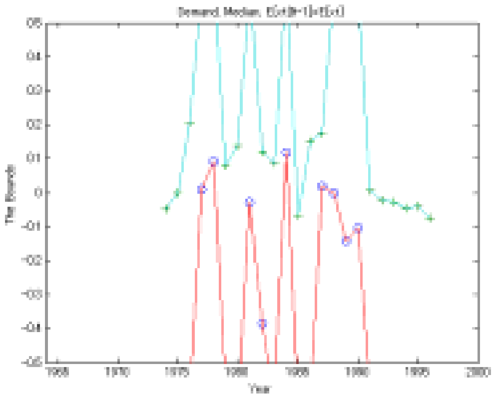
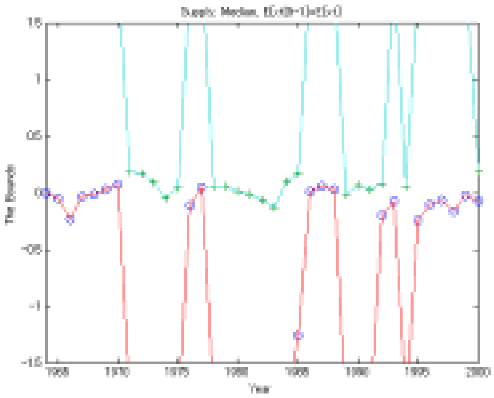
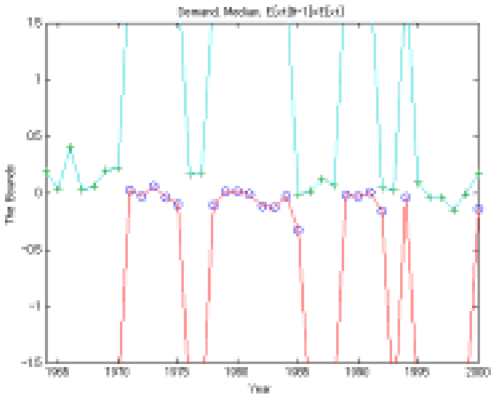
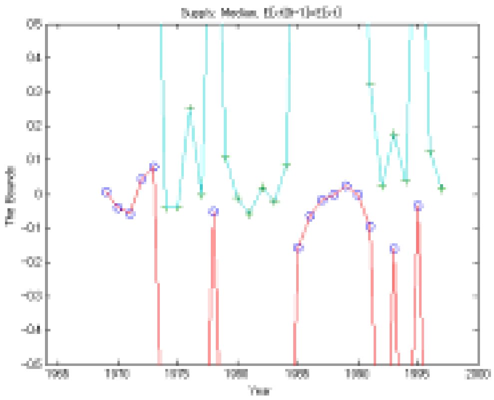
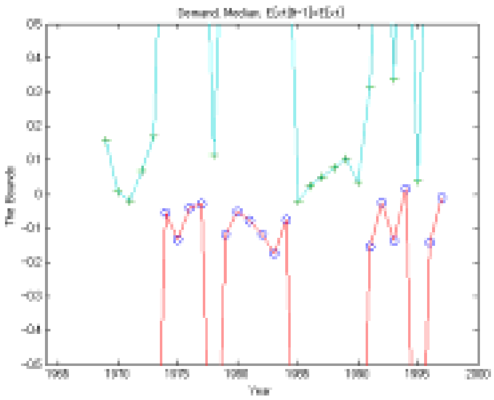
	Macro supply shocks μ_t	Macro demand shocks ν_t
Hong Kong		
Singapore		
Malaysia		

Figure 2 continued

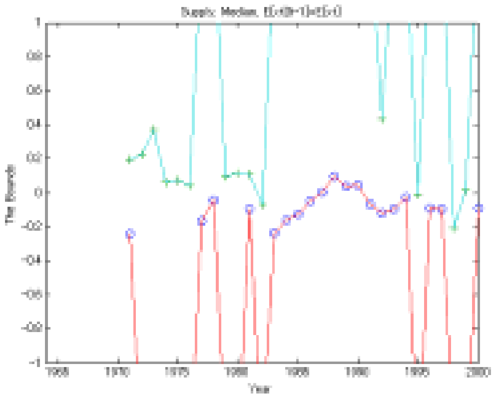
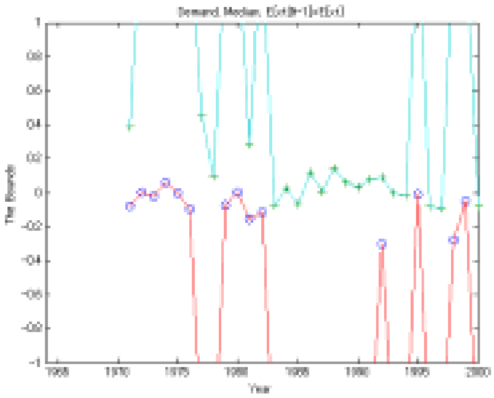
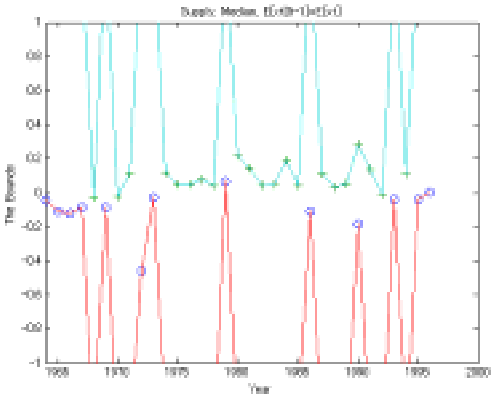
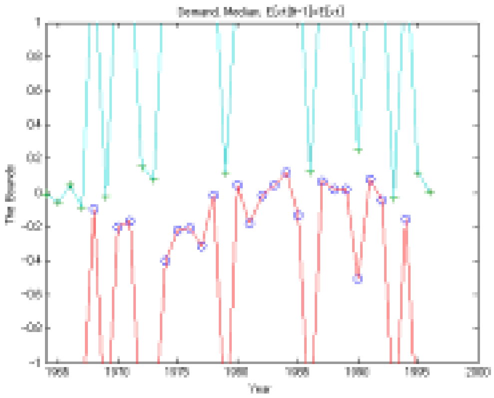
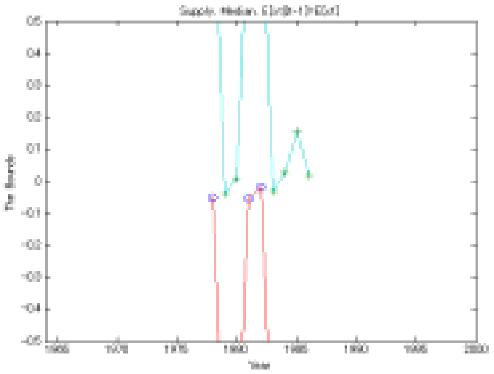
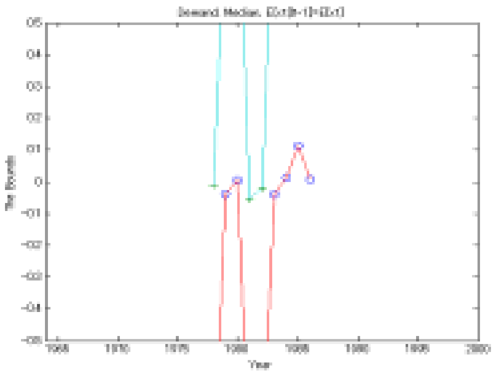
	Macro supply shocks μ_t	Macro demand shocks ν_t
Indonesia		
Philippines		
China		

Figure 3. The estimates of the bounds on macro supply and demand shocks: μ_t and ν_t (ε_t, ξ are assumed to follow normal distributions with 0 mean and the means of the variables over time are taken as a normalization.)

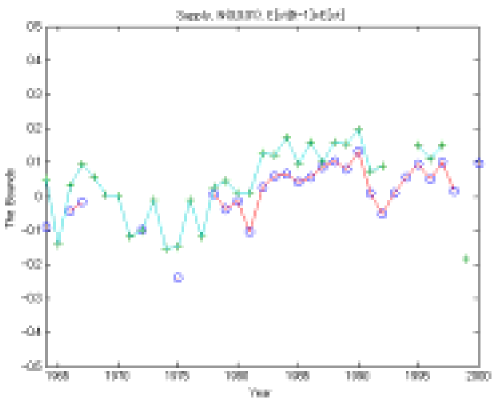
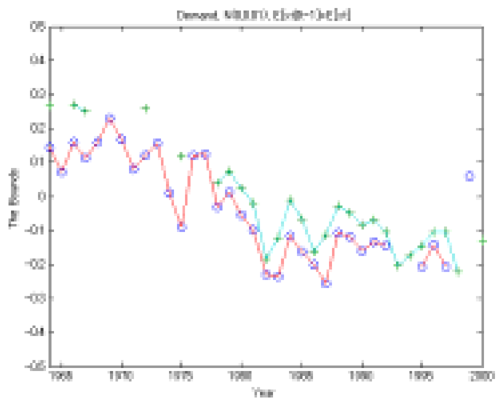
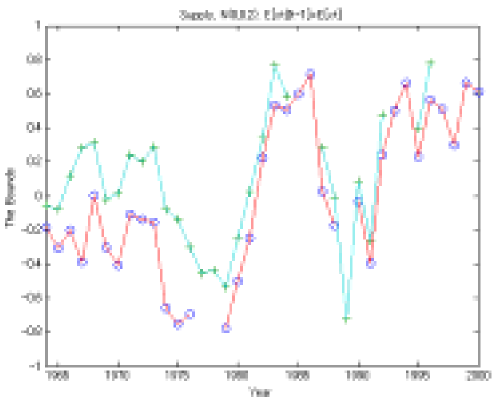
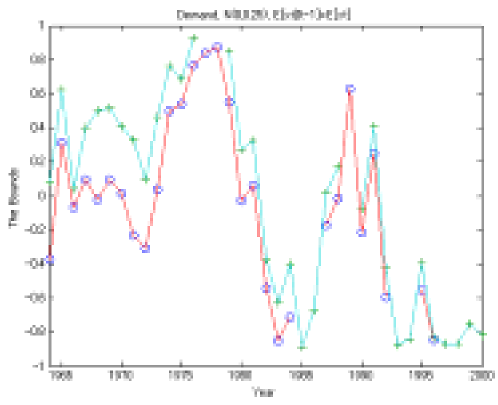
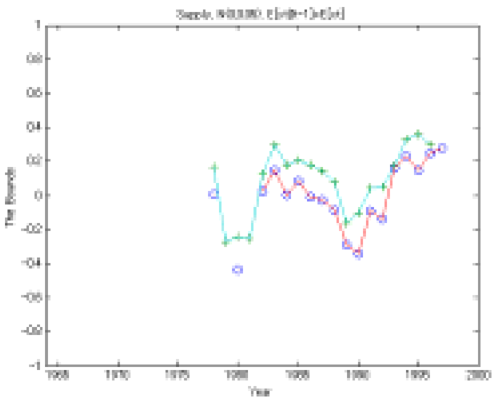
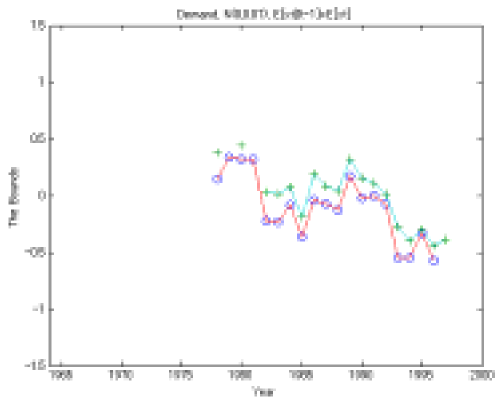
	Macro supply shocks μ_t	Macro demand shocks ν_t
Japan		
Korea		
Taiwan		

Figure 3 continued

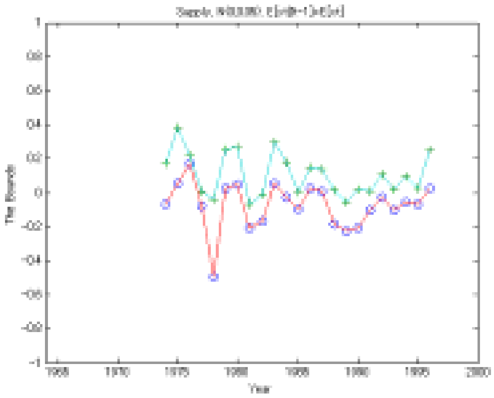
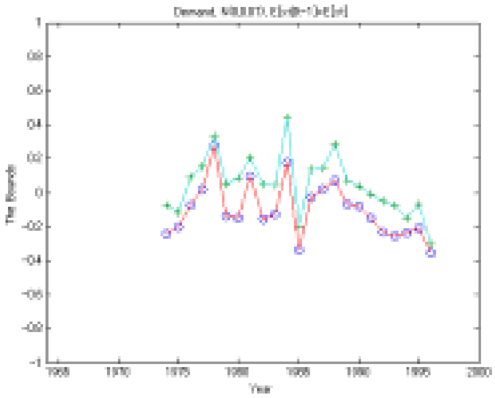
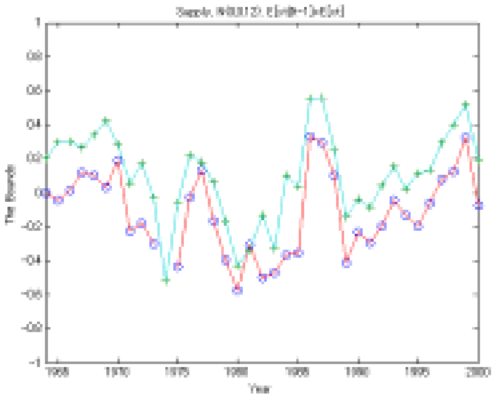
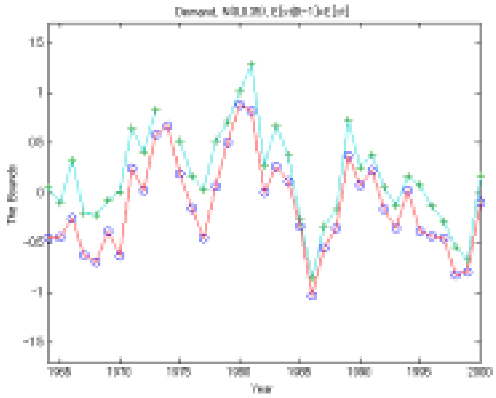
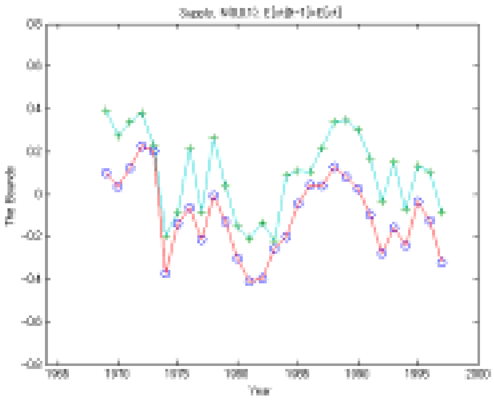
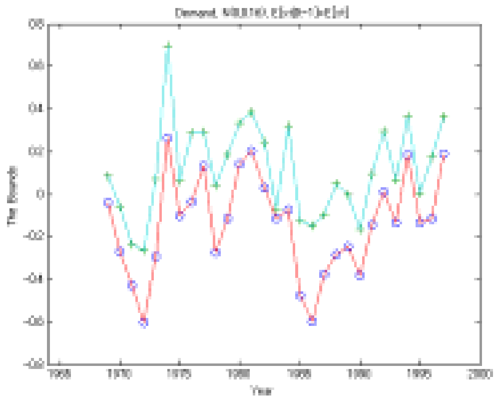
	Macro supply shocks μ_t	Macro demand shocks ν_t
Hong Kong		
Singapore		
Malaysia		

Figure 3 continued

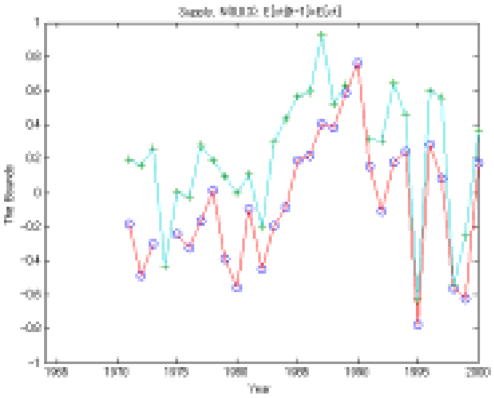
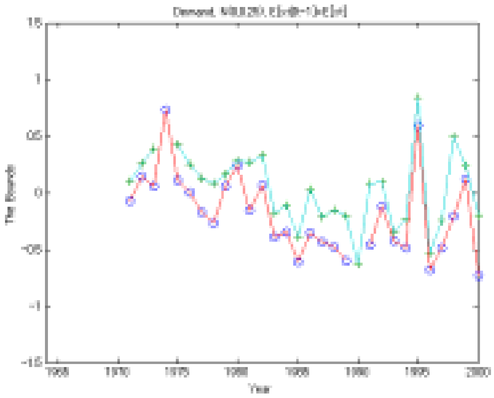
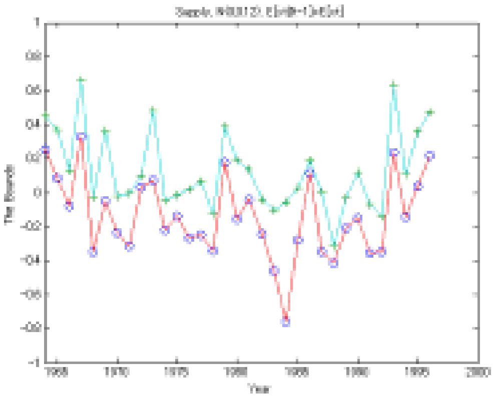
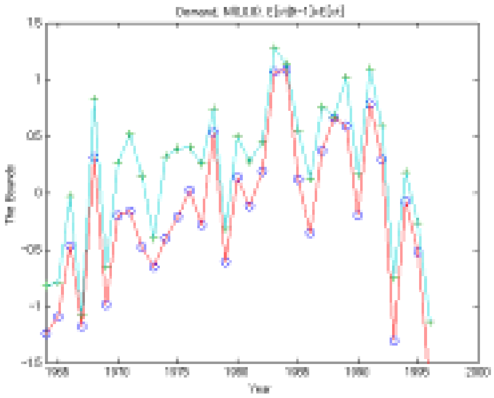
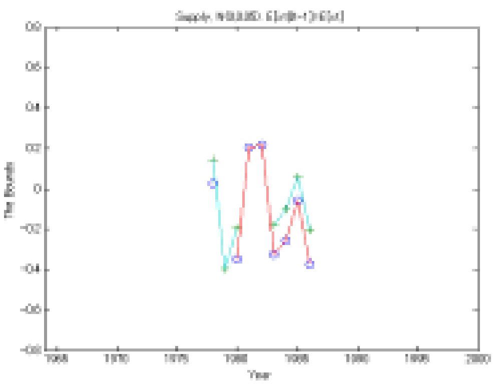
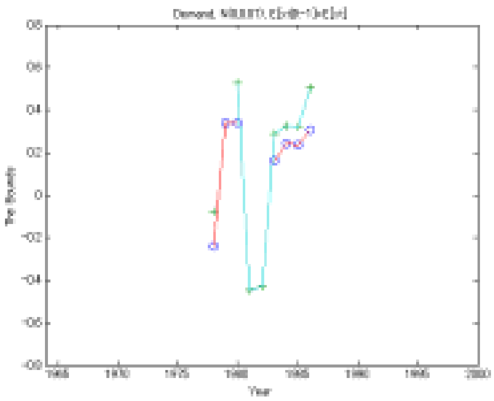
	Macro supply shocks μ_t	Macro demand shocks ν_t
Indonesia		
Philippines		
China		

Figure 4. The estimates of the bounds on macro supply and demand shocks: μ_t and ν_t (the medians of ε_t, ξ_t are assumed 0 and the lagged variables are taken as a normalization.)

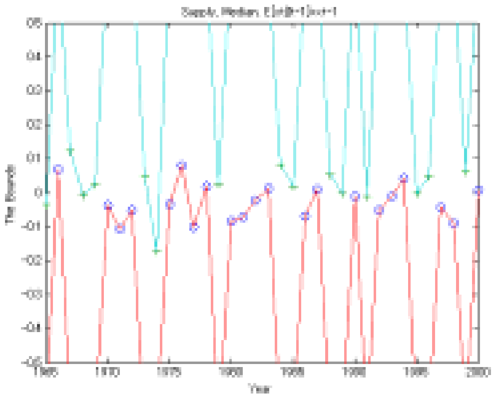
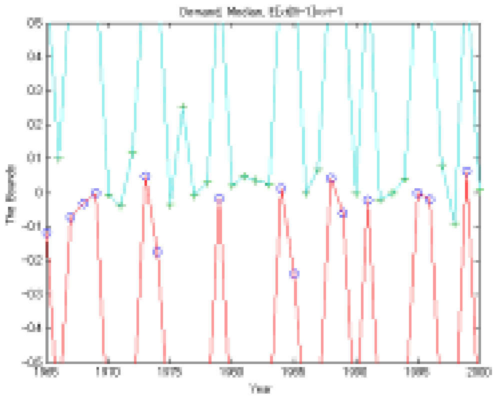
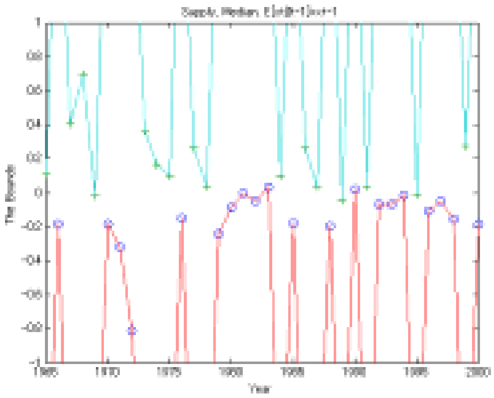
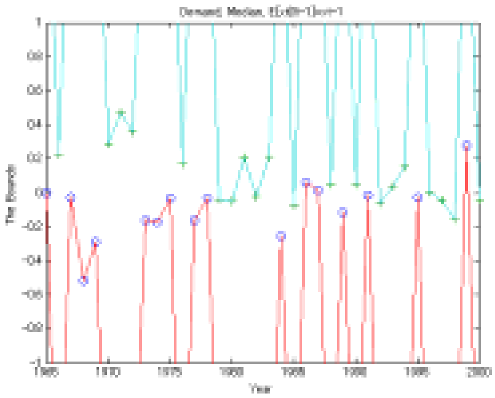
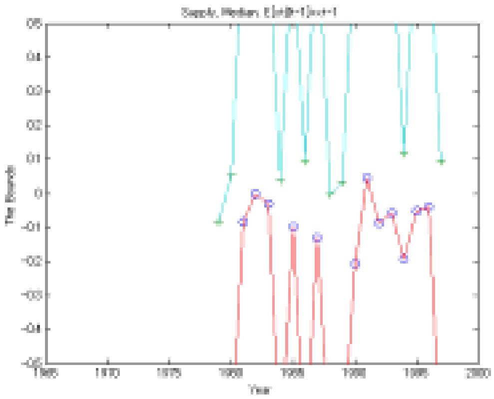
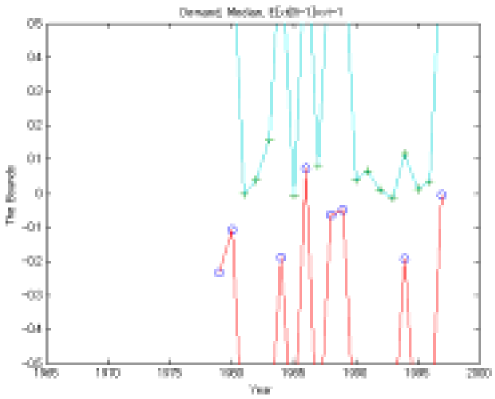
	Macro supply shocks μ_t	Macro demand shocks ν_t
Japan		
Korea		
Taiwan		

Figure 4 continued

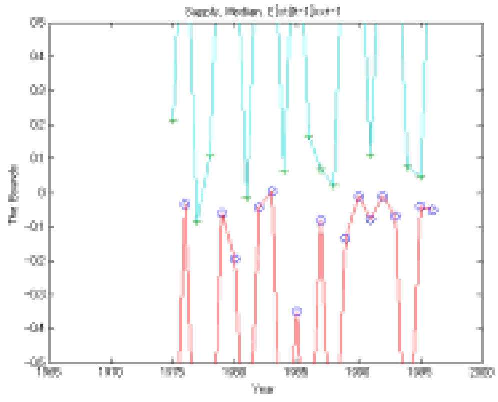
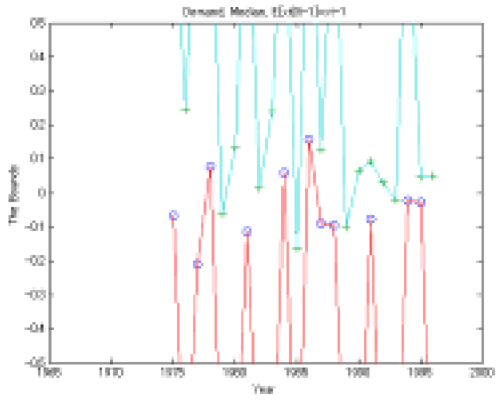
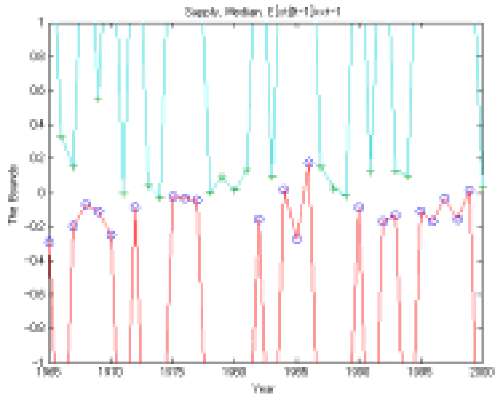
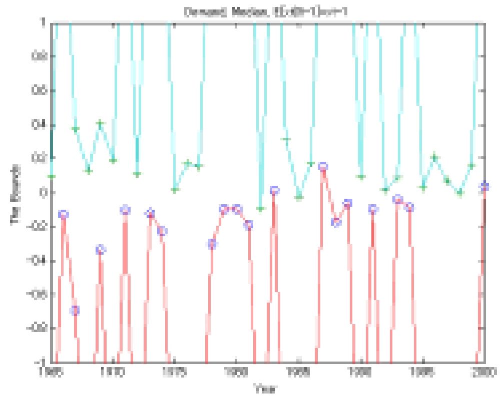
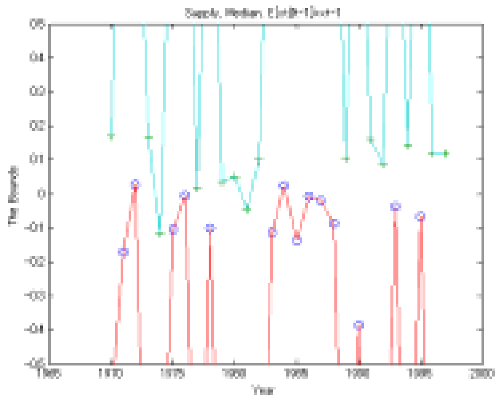
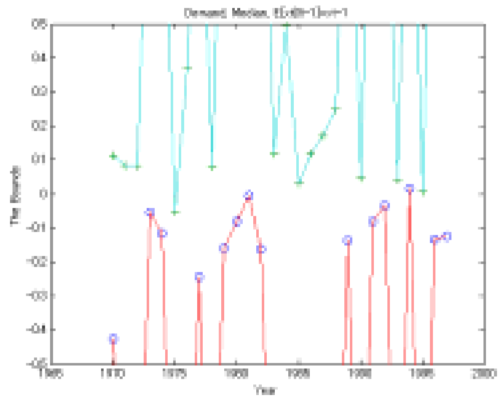
	Macro supply shocks μ_t	Macro demand shocks ν_t
Hong Kong		
Singapore		
Malaysia		

Figure 4 continued

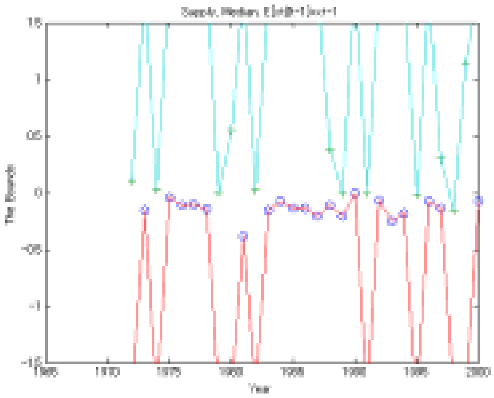
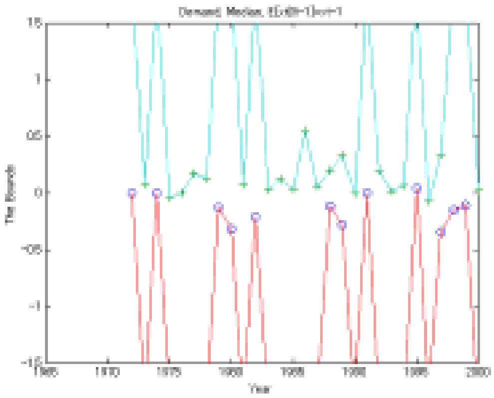
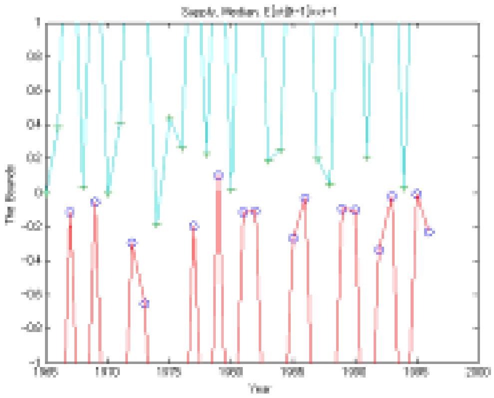
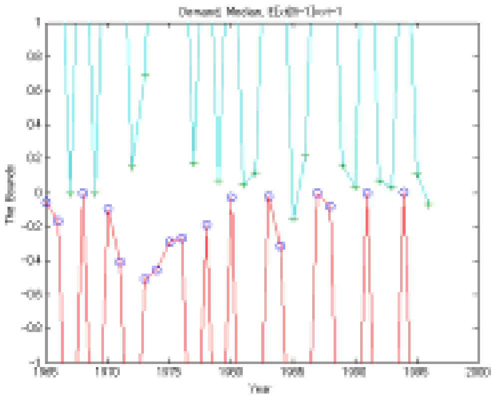
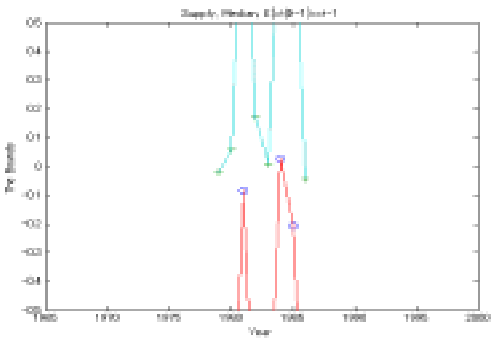
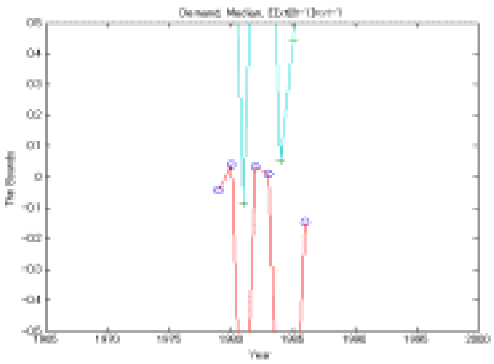
	Macro supply shocks μ_t	Macro demand shocks ν_t
Indonesia		
Philippines		
China		

Figure 5. The estimates of the bounds on macro supply and demand shocks: μ_t and ν_t (ε_t, ξ_t are assumed to follow normal distributions and the lagged variables are taken as a normalization)

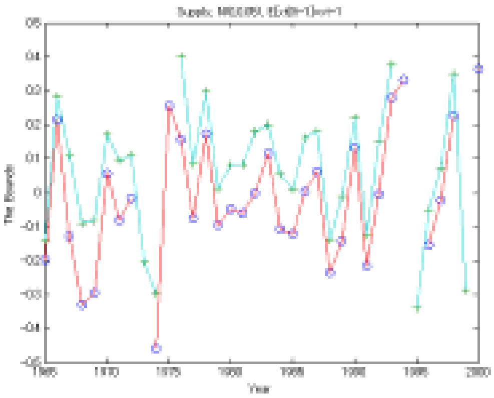
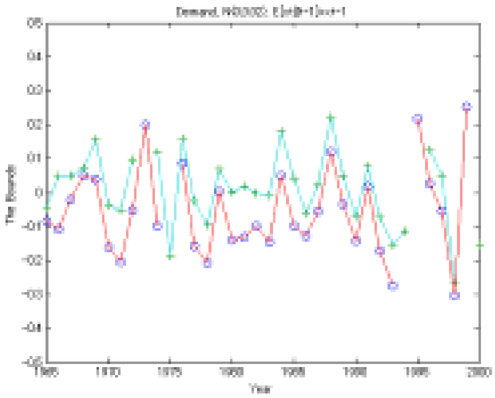
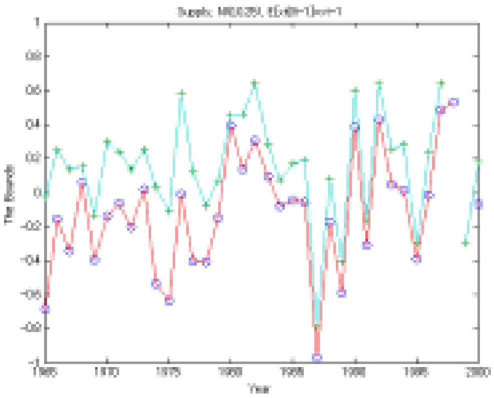
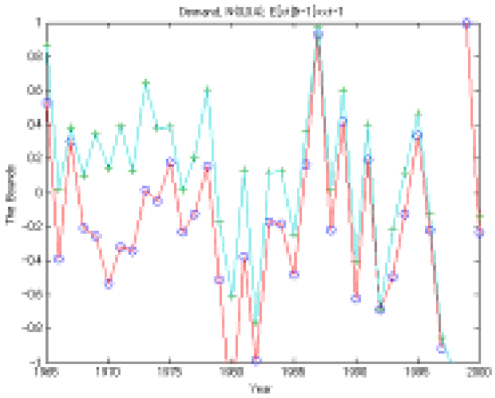
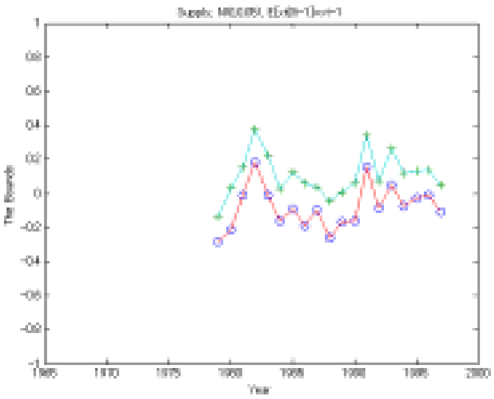
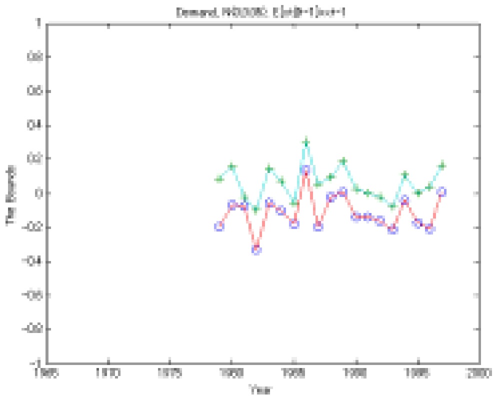
	Macro supply shocks μ_t	Macro demand shocks ν_t
Japan		
Korea		
Taiwan		

Figure 5 continued

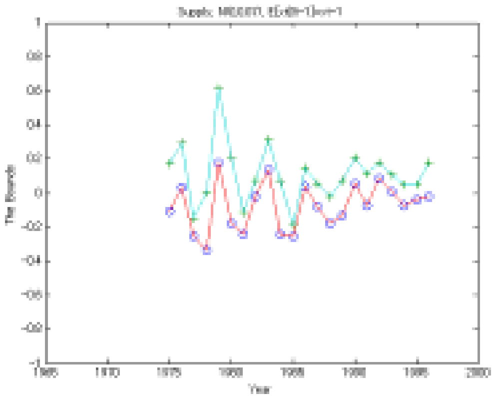
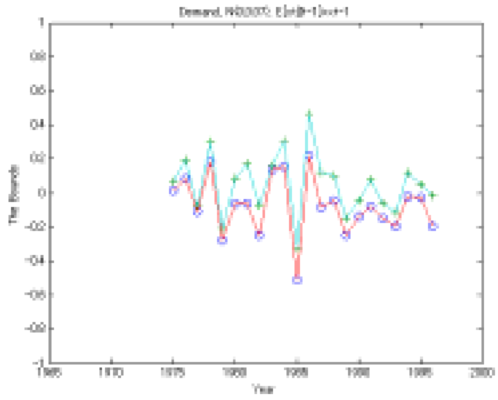
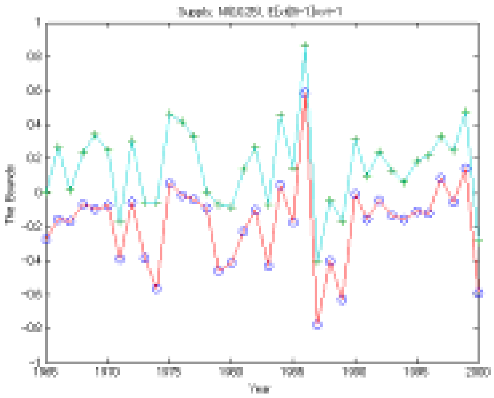
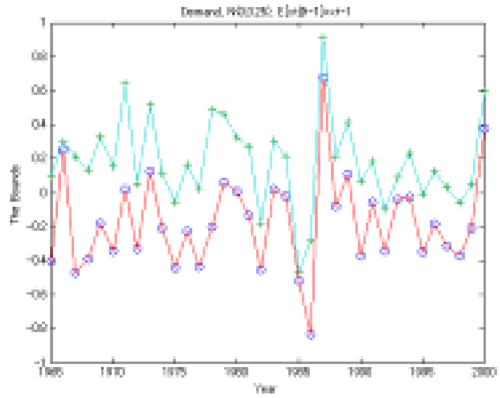
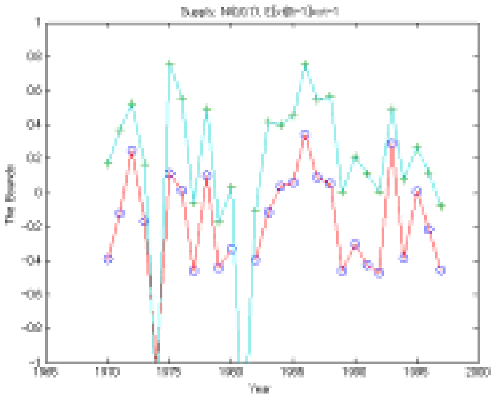
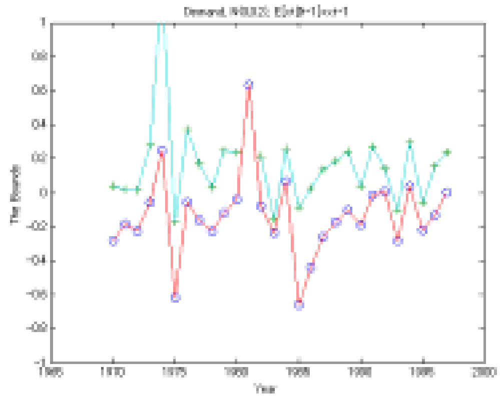
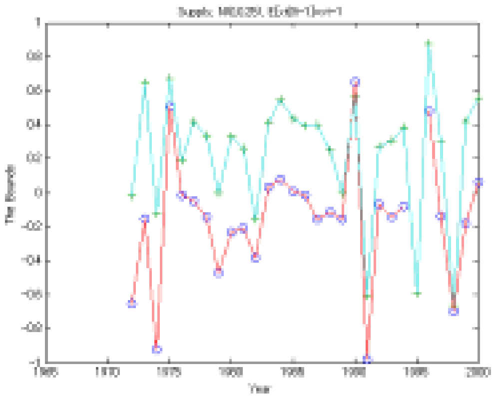
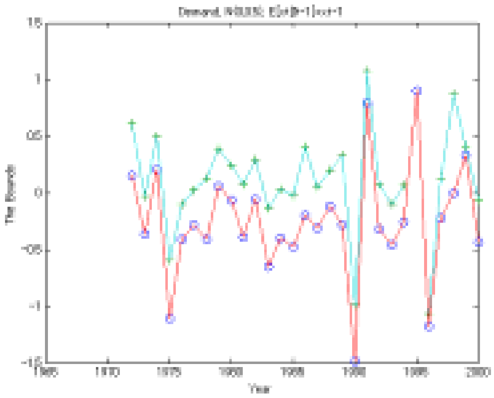
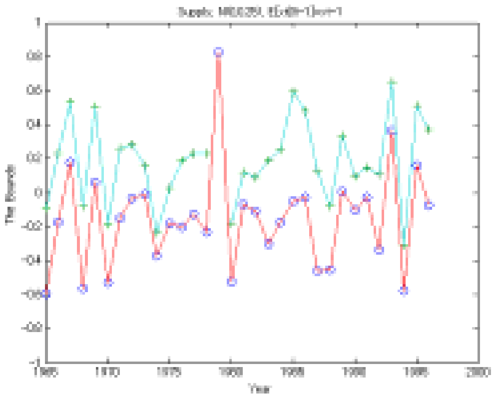
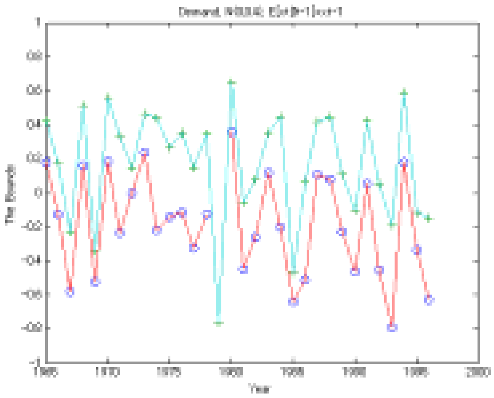
	Macro supply shocks μ_t	Macro demand shocks ν_t
Hong Kong		
Singapore		
Malaysia		

Figure 5. continued

	Macro supply shocks μ_t	Macro demand shocks ν_t
Indonesia		
Philippines		
China