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Abstract

The purpose of this paper is to analyze how changes in market psychology can be the source of world business cycles. The analysis is based on a two-country monetary model with the cash-in-advance constraint. In the model, we assume that international transmissions of the productivity shocks are small. However, when we investigate its dynamic property, we find that there exist stationary sunspot equilibria either when the relative risk aversion of the utility function is large or when positive external effects in production are large. In both cases, stationary sunspot equilibria are more likely outcome for the world aggregate output than for country-specific output. The result holds even when two countries do not have symmetric economic structure. Therefore, even if the fundamental value shows small cross-country output correlations, market psychology can cause large synchronization of business cycles under rational expectations.

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1. Introduction

The source of international business cycles is one of extensively debated topics in international macroeconomics. In previous literature, a large number of empirical studies have noted an approximate synchronization between different national business cycles and have hypothesized the existence of "world business cycles".[1] The empirical evidence is, however, somewhat paradoxical because the other empirical studies have shown that the international transmission of economic fluctuations is not large.[2] One plausible explanation for the empirical evidence is the common exogenous shock hypothesis in which business cycle synchronization is caused by exogenous global shocks such as oil shocks.[3] In particular, oil price shocks in 1973 and 1979 had substantial effects on economies around the world. However, it is hard to believe that we have experienced highly frequent fundamental global shocks that caused business cycle synchronization. In addition, several empirical studies report that correlations of output across countries are much larger than those of productivity.[4]

The purpose of this paper is to investigate whether changes in market psychology can be another source of world business cycles even if agents form rational expectations. The model is based on a two-country monetary model with country-specific cash-in-advance constraints.[5] We assume that international transmission of economic fluctuations is not large. We then investigate the dynamic property of this two country monetary model and explore the implications of extraneous (non-fundamental) shocks for world business cycles.

In the following two-country model, productivity shocks always have strong positive impacts on the domestic output. However, international transmissions of the productivity

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1 In two-country equilibrium frameworks, examples of these studies include Backus, Kehoe, and Kydland (1992), Devereux, Gregory, and Smith (1992), and Stockman and Tessar (1995).

2 For example, Fair (1982) provides quantitative estimates of international linkages from his econometric model. In his tables, we can easily see that international linkages are very small except for linkages from the United States to Canada and from Germany to other European countries. Oudiz and Sachs (1984) review evidence on policy multipliers in two large-scale econometric models, the Japanese Economic Planning Agency (EPA) model and the Federal Reserve Board's Multicountry model (MCM). They conclude that the cross-country policy multipliers are generally quite small, although the United States has some effect on West Germany and Japan.

3 For example, running a vector autoregression, Dellas (1986) found that the lagged effects of one economy on another were less significant than the contemporaneous effects and concluded that common shocks explain the existence of world business cycles.

4 See, for example, Costello (1993), Backus, Kehoe, and Kydland (1995), and Stockman and Tessar (1995).

5 This type of cash cash-in-advance constraints was extensively studied in open macroeconomics (e.g., Helpman (1981), Lucas (1982), Aschauer and Greenwood (1983), King, Wallace and Weber (1992), Grilli and Roubini (1992), and Ch.8A in Obstfeld and Rogoff (1997)).

shocks are small under reasonable parameters. Therefore, unless productivity shocks are highly correlated across countries, it is unlikely that the fundamental value of output in country 1 has a strong correlation with that in country 2.

However, when we investigate the dynamic property of this monetary model, we find that there exist stationary sunspot equilibria either when the relative risk aversion of the utility function is large or when positive external effects in production are large. In both cases, stationary sunspot equilibria are more likely outcome for the world aggregate output than for country-specific output. This is because a raise of the expected future domestic output has a positive impact on both domestic and foreign current outputs. However, even the international linkage is small, extraneous uncertainty tends to cause strong synchronization of business cycles. In addition, the result does not depend on the assumption that two countries have symmetric economic structure.

In the previous literature, several authors point out there can exist sunspot equilibria in cash-in-advance models (see Woodford (1992)).[6] In particular, Woodford (1991) and King, Wallace and Weber (1992) find the existence of sunspot equilibria in open economy models.[7] However, because their concerns was not on world business cycles, it has not been clear whether extraneous shocks, that is, changes in market psychology can be the source of world business cycles.[8]

On the other hand, several previous empirical studies have stressed the role of investor psychology in explaining the international transmission of exogenous shocks. For example, Shiller, Kon-Ya, and Tsutsui (1991) show that international stock market crash in the October 1987 was attributable to changes in investor psychology both in the United States and Japan. Engle, Ito, and Lin (1990) investigate the international transmission of intra-daily asset volatility in the foreign exchange market and conclude that various market failure such as fads, bubbles, bandwagons, etc. can be the explanation for their finding. Our theoretical result is consistent with these empirical studies because changes in market psychology can be one important source of world business cycles in our model.

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[6] Sunspot equilibria were originally explored by Azariadis (1981) and Cass and Shell (1983). Michener and Ravikumar (1994) find the existence of chaos in the cash-in-advance model. On the dynamic stability of the other closed monetary models, Benhabib and Day (1982) and Grandmont (1985) characterize the chaotic phenomena in overlapping generation models. In addition, Matsuyama (1990, 1991) and Fukuda (1993a, 1997) find that models of money in the utility function can produce sunspots and chaotic dynamic paths.

[7] Weil (1991) and Fukuda (1994) explore the same issue in models of money in the utility function.

[8] In the optimal growth model, Nishimura and Yano (1993) investigate the existence of endogenous cycles in the world economy. However, they pay little attention on the issues of world business cycles discussed in this paper.

The paper proceeds as follows. The next section presents a basic two-country model with cash-in-advance constraints and section 3 derives its equilibrium conditions. Section 4 examines the existence of sunspot equilibria in our model and section 5 presents some simulation results. Section 6 extends our model to the case where production functions are different between two countries. Section 7 summarizes our main results and refers to their possible extension.

2. The model

We consider a world economy with two countries, country 1 and country 2. Each country has identical agents with constant population. There is two, perishable, tradable consumption goods, A and B. The consumption good A is produced only in country 1, while the consumption good B is produced only in country 2. However, all agents consume both of the consumption goods.

Each representative agent in country i ($i = 1, 2$) maximizes the following expected utility function :

$$(1) \quad E_t \sum_{j=0}^{\infty} \beta^j \left[U(c^{Ai}_{t+j}, c^{Bi}_{t+j}) - V(n^i_{t+j})\right], \qquad 0 < \beta < 1,$$

where E_t is the conditional expectation operator based on information at period t, c^{Ai}_t is consumption in country i of the good A, c^{Bi}_t is consumption in country i of the good B, and n^i_t is labor input in country i at period t. The utility functions and the discount factor β are common to both countries. In the following analysis, we specify the utility functions as follows

$$(2a) \quad U(c^{Ai}_t, c^{Bi}_t) \equiv (c^{Ai\,\alpha}_t\, c^{Bi\,1-\alpha}_t)^{\gamma} / \gamma, \qquad \text{where} \quad 1/2 < \alpha < 1, \quad \gamma < 1,$$

$$(2b) \quad V(n^i_t) \equiv n^{i\,1+\delta}_t / (1+\delta), \qquad \text{where} \quad \delta > 0.$$

The condition that $\alpha > 1/2$ indicates that the agent places more weight on the domestic consumption good than on the foreign consumption good.

Define p^A_t as the price of the good A in terms of country 1 currency, p^B_t as the price of the good B in terms of country 2 currency, and e_t as the nominal exchange rate in terms of country 1 currency. Then, the budget constraint in country 1 in terms of country 1 currency is written as

$$(3a)\quad p^{A}_{t}\,c^{A1}_{t} + e_t\,p^{B}_{t}\,c^{B1}_{t} + M^{11}_{t+1} + e_t M^{21}_{t+1} - T^{1}_{t} + p^{A}_{t}\,B^{1}_{t+1}$$
$$\leq\ p^{A}_{t}\,y^{1}_{t} + M^{11}_{t} + e_t M^{21}_{t} + p^{A}_{t}\,(1+r_t^{1})B^{1}_{t}.$$

Similarly, the budget constraint in country 2 in terms of country 2 currency is written as

$$(3b)\quad (1/e_t)p^{A}_{t}\,c^{A2}_{t} + p^{B}_{t}\,c^{B2}_{t} + (1/e_t)M^{12}_{t+1} + M^{22}_{t+1} - T^{B}_{t} + p^{B}_{t}\,B^{2}_{t+1}$$
$$\leq\ p^{B}_{t}\,y^{2}_{t} + (1/e_t)M^{12}_{t} + M^{22}_{t} + p^{B}_{t}(1+r_t^{2})B^{2}_{t},$$

where B^{i}_{t} is the sum of net saving in country i, r_t^{i} is the real interest rate in terms of country i currency, and T^{i}_{t} is the lump-sum tax (or transfer if negative) in country i.

In the above budget constraints, the income in country i is denoted by y^{i}_{t}. We assume that y^{i}_{t} is equal to the total output of the good A when $i = 1$ and is equal to the total output of the good B when $i = 2$. We also assume that the production function in each country is written as follows:

$$(4)\quad y^{i}_{t} = \mathrm{H}\exp(w^{i}_{t})\, n^{i\ \varepsilon}_{t}\, N^{i\ \eta}_{t}, \qquad 0 < \varepsilon < 1,\ 0 < \eta$$

where w^{i}_{t} is the zero-mean productivity shock in country i. The productivity shock w^{i}_{t} follows AR(1) process:

$$(5)\quad w^{i}_{t} = \rho\, w^{i}_{t-1} + \xi^{\,i}_{t}, \qquad 0 < \rho < 1,$$

where $\xi^{\,i}_{t}$ follows normal distribution $N(0, \sigma^2)$ which is independent over time.

A key characteristic in the above production function is that the output in country i depends not only on its labor input, n^{i}_{t}, but also on the average labor input in country i, N^{i}_{t}. Because $0 < \varepsilon < 1$, this production function is decreasing returns to scale in terms of individual labor input. However, when $\varepsilon + \eta > 1$, the aggregate production function is increasing returns to scale in labor.

In the budget constraints (3a, b), M^{1i}_{t} is the amount of currency 1 held by the agent in country i at the beginning of period t, and M^{2i}_{t} is the amount of currency 2 held by the agent in country i at the beginning of period t. We assume that agents must set aside currency 1 in advance to purchase the good A and currency 2 in advance to purchase the good B.[9] The cash-in-advance constraints are thus given by

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[9] Zhou (1997) shows that this type of cash-in-advance constraint can be derived in a search theoretic monetary model.

(6a) $p^{A}_{t}\, c^{Ai}_{t} \leqq M^{1i}_{t}$,

(6b) $p^{B}_{t}\, c^{Bi}_{t} \leqq M^{2i}_{t}$.

The above constrained optimization problem for the agent in country 1 are maximized by differentiating the following Lagrangean by c^{A1}_{t}, c^{B1}_{t}, n^{1}_{t}, M^{11}_{t+1}, M^{21}_{t+1}, and B^{1}_{t+1}.

$$
\begin{aligned}
L = E_t \textstyle\sum_{j=0}^{\infty} \beta^{j}\ [&U(c^{A1}_{t+j}, c^{B1}_{t+j}) - V(n^{1}_{t+j}) \\
&+ \lambda_{t+j}\{p^{A}_{t+j}\, c^{A1}_{t+j} + e_{t+j}\, p^{B}_{t+j}\, c^{B1}_{t+j} + M^{11}_{t+j+1} + e_{t+j} M^{21}_{t+j+1} - T^{1}_{t+j} + p^{A}_{t+j} B^{1}_{t+j+1} \\
&\quad - p^{A}_{t+j}\, \mathrm{H} \exp(w^{1}_{t+j})\, n^{1\ \varepsilon}_{t+j} N^{1\ \eta}_{t+j} - M^{11}_{t+j} - e_{t+j} M^{21}_{t+j} - p^{A}_{t+j}\,(1+r_{t+j}^{1}) B^{1}_{t+j}\} \\
&+ \phi_{t+j}(p^{A}_{t+j}\, c^{A1}_{t+j} - M^{11}_{t+j}) + \phi_{t+j}(p^{B}_{t+j}\, c^{B1}_{t+j} - M^{21}_{t+j})\ ].
\end{aligned}
$$

Assuming that the cash-in-advance constraints (6a, b) are binding, the first-order conditions for the agent in country 1 are

(7a) $\alpha\, (c^{B1}_{t}/c^{A1}_{t})^{1-\alpha} (c^{A1\ \alpha}_{t}\, c^{B1\ 1-\alpha}_{t})^{\gamma-1} = \lambda_t p^{A}_{t} + \phi_t p^{A}_{t}$,

(7b) $(1-\alpha)\, (c^{A1}_{t}/c^{B1}_{t})^{\alpha} (c^{A1\ \alpha}_{t}\, c^{B1\ 1-\alpha}_{t})^{\gamma-1} = \lambda_t e_t\, \mathrm{p}^{B}_{t} + \phi_t p^{B}_{t}$,

(7c) $n^{1\ \delta}_{t} = \lambda_t p^{A}_{t} \mathrm{H} \exp(w^{1}_{t})\ \varepsilon\ n^{1\ \varepsilon-1}_{t}\ N^{1\ \eta}_{t}$,

(7d) $\lambda_t = \beta E_t(\lambda_{t+1} + \phi_{t+1})$,

(7e) $e_t \lambda_t = \beta E_t(e_{t+1} \lambda_{t+1} + \phi_{t+1})$,

(7f) $\lambda_t p^{A}_{t} = \beta\, (1+r_{t+j}^{1})\, E_t(\lambda_{t+1}\, p^{A}_{t+1})$.

Noting that $y^{1}_{t} = \mathrm{H} \exp(w^{1}_{t})\, n^{1\ \varepsilon}_{t} N^{1\ \eta}_{t}$ and $n^{1}_{t} = N^{1}_{t}$ in equilibrium, (7a) – (7f) lead to

(8a) $c^{A1}_{t}/c^{B1}_{t} = \{\alpha/(1-\alpha)\}(e_t\, p^{B}_{t}/p^{A}_{t})$,

(8b) $y^{1\ \mu-1}_{t} = \beta\ \alpha\ \varepsilon\ \mathrm{H}^{\mu} \exp(w^{1}_{t})\, E_t\, [(c^{B1}_{t+1}/c^{A1}_{t+1})^{1-\alpha} (c^{A1\ \alpha}_{t+1}\, c^{B1\ 1-\alpha}_{t+1})^{\gamma-1} (p^{A}_{t}/p^{A}_{t+1})]$,

(8c) $1 + r_t^{1} = (1/\beta)\, E_t\, [(y^{1}_{t}/y^{1}_{t+1})^{\mu-1} \{\exp(w^{1}_{t+1})/\exp(w^{1}_{t})\}^{\mu}]$,

where $\mu \equiv (1+\delta)/(\varepsilon+\eta)$.

Similarly, the first-order conditions for the agent in country 2 lead to

(9a) $c^{B2}_{t}/c^{A2}_{t} = \{\alpha/(1-\alpha)\}(p^{A}_{t}/\, e_t\, p^{B}_{t})$,

(9b) $y^{2\ \mu-1}_{t} = \beta\ \alpha\ \varepsilon\ \mathrm{H}^{\mu} \exp(w^{2}_{t})\, E_t\, [(c^{A2}_{t+1}/c^{B2}_{t+1})^{1-\alpha} (c^{B2\ \alpha}_{t+1}\, c^{A2\ 1-\alpha}_{t+1})^{\gamma-1} (p^{B}_{t}/p^{B}_{t+1})]$,

(9c) $1 + r_t^{2} = (1/\beta)\, E_t\, [(y^{2}_{t}/y^{2}_{t+1})^{\mu-1} \{\exp(w^{2}_{t+1})/\exp(w^{2}_{t})\}^{\mu}]$.

3. Market Equilibrium

In the following analysis, we assume that the monetary authority of each country keeps the total supply of its currency constant. We also assume that government revenue through money creation in country i is always balanced by the exogenous change in the lump-sum transfer to the agent in country i.

Then, denoting the total nominal supply of currency i by M^i, it holds that $T^i_t = 0$ and $M^{i1}_t + M^{i2}_t = M^i$ for $i = 1$ and 2. Therefore, the equilibrium conditions in the good markets, the money markets, and the foreign exchange market lead to

(10a) $c^{A1}_t + c^{A2}_t = y^1_t, \quad c^{B1}_t + c^{B2}_t = y^2_t,$

(10b) $p^A_t y^1_t = M^1, \quad p^B_t y^2_t = M^2,$

(10c) $e_t = M^1/M^2.$

One important property of these equilibrium conditions is that they dichotomize. That is, all real equilibrium quantities are independent of the levels of the nominal money stocks, while the levels of equilibrium prices and the nominal exchange rate are determined by the money equation. Hence, the traditional Quantity Theory (neutrality of money) holds in our model.

The equilibrium conditions (10a, b, c) with (8a) and (9a) lead to

(11a) $c^{A1}_t = \alpha\ y^1_t, \quad c^{B2}_t = \alpha\ y^2_t,$

(11b) $c^{A2}_t = (1-\alpha) y^2_t, \quad c^{B1}_t = (1-\alpha) y^2_t,$

(11c) $B^1_t = (1-\alpha)\ (y^1_t - y^2_t) = - B^2_t.$

Substituting (11a, b) into the first-order conditions (8b) and (9b), we obtain

(12a) $y^{1\ \mu}_t = \mathrm{J} \exp(w^1_t) \mathrm{E}_t\, (y^{1\ \alpha\gamma}_{t+1}\ y^{2\ (1-\alpha)\gamma}_{t+1}),$

(12b) $y^{2\ \mu}_t = \mathrm{J} \exp(w^2_t) \mathrm{E}_t\, (y^{1\ (1-\alpha)\gamma}_{t+1}\ y^{2\ \alpha\gamma}_{t+1}),$

where $\mathrm{J} \equiv \beta\ \alpha^{\alpha\gamma}(1-\alpha)^{(1-\alpha)\gamma}\ \varepsilon\, \mathrm{H}^{\mu}$.

Equations (12a) and (12b) determine the dynamic system in our model. In order to obtain the fundamental values of y^1_t and y^2_t, we suppose that

(13a) $y^1_t = \Gamma \exp(a\, w^1_t) \exp(b\, w^2_t),$

(13b) $y^2_t = \Gamma \exp(b\, w^1_t) \exp(a\, w^2_t)$,

where Γ, a, and b are constant unknown parameters. Then, because an innovation ξ^i_t in w^i_t (i = 1, 2) follows normal distribution N(0, σ^2), it holds that $E_t\,(y^1_{t+1}{}^{(1-\alpha)\gamma}\, y^2_{t+1}{}^{\alpha\gamma}) = \Gamma^{\gamma} E_t \exp[\alpha\,\gamma\, a\, w^1_{t+1} + (1-\alpha)\,\gamma\, b\, w^2_t] = \Gamma^{\gamma}\exp([\{\alpha a\}^2 + \{(1-\alpha) b\}^2](\gamma\sigma)^2/2)\, E_t \exp[\alpha\,\rho\,\gamma\, a\, w^1_t + (1-\alpha)\,\rho\,\gamma\, b\, w^2_t]$. Therefore, the method of undetermined coefficients lead to

(14a) $a = (\mu - \rho\,\alpha\,\gamma)/[\{\mu - \rho\,(2\alpha - 1)\gamma\}(\mu - \rho\,\gamma)]$,

(14b) $b = (1-\alpha)\rho\,\gamma/[\{\mu - \rho\,(2\alpha - 1)\gamma\}(\mu - \rho\,\gamma)]$,

(14c) $\Gamma = J^{1/(\mu-\gamma)} \exp([\{\alpha a\}^2 + \{(1-\alpha) b\}^2](\gamma\sigma)^2/[2(\mu - \gamma)])$.

In the following analysis, we assume that $\mu \equiv (1+\delta)/(\varepsilon + \eta) > \rho\,\gamma$. Then, because $a > 0$ in (14a), the productivity shocks always have positive effects on the domestic output. On the other hand, the productivity shocks have positive effects on the foreign output when $\gamma > 0$ and negative effects on the foreign output when $\gamma < 0$. However, since b is small when either $1-\alpha$, ρ, or γ is close to zero, international transmissions of the productivity shocks are small either when the consumption is highly biased to the home product, when productivity shocks are less persistent, or when the utility function is close to log-linear type. Therefore, when one of these conditions is satisfied, it is unlikely that the fundamental value of output in country 1 has a strong correlation with that in country 2 unless w^1_t is highly correlated with w^2_t.

For example, Figure 1 plots impulse response functions of log y^1_t and log y^2_t to a productivity shock in country 1 for two alternative parameters. In calculating the impulse response functions, we set that an innovation in the productivity shock ξ^1_t is equal to 1 when t = 1 and 0 otherwise. In addition, we assume that $w^2_t = 0$ for all t and set that $\alpha = 0.8$, H=1, $\varepsilon = 0.8$, $\sigma^2 = 1$, and $\beta = 0.9$.

Figure 1a shows the impulse response functions of log y^1_t and log y^2_t for a parameter set that $\rho = 0.9$, $\delta = 2$, $\eta = 0.2$, and $\gamma = -4$. In the figure, the productivity shocks have strong positive effects on the domestic output. However, because $\gamma < 0$, the productivity shocks have negative effects on the foreign output. In addition, the negative effects are very small in their magnitude.

Figure 1b shows the impulse response functions of log y^1_t and log y^2_t for the a parameter set that $\rho = 0.6$, $\delta = 0.4$, $\eta = 1.2$, and $\gamma = 0.8$. As in the figure 1a, the productivity shocks have strong positive effects on the domestic output in figure 1b. In addition, because $\gamma > 0$, the productivity shocks have positive effects on the foreign output. However, the effects on the foreign output are negligible in their magnitude.

4. The Existence of Sunspot Equilibria

In this section, we investigate whether the dynamics (12a) and (12b) can have sunspot equilibria under reasonable conditions. In the analysis, we consider the case where there exists no stochastic shock in the economy. Then, (12a, b) lead to a pair of difference equations for the perfect foresight equilibrium dynamics of two logged output levels :

(15a) $\log y^1_t = \log J + (\alpha\ \gamma / \mu) \log y^1_{t+1} + \{(1-\alpha)\ \gamma / \mu\} \log y^2_{t+1},$

(15b) $\log y^2_t = \log J + \{(1-\alpha)\ \gamma / \mu\} \log y^1_{t+1} + (\alpha\ \gamma / \mu) \log y^2_{t+1},$

or equivalently,[10]

(16a) $\log y^1_t + \log y^2_t = 2 \log J + (\gamma / \mu)(\log y^1_{t+1} + \log y^2_{t+1}),$

(16b) $\log y^1_t - \log y^2_t = \{(2\alpha - 1)\ \gamma / \mu\}(\log y^1_{t+1} - \log y^2_{t+1}).$

It is well-known that a one-dimensional map $x_t = f(x_{t+1})$ has stationary sunspot equilibria around its steady state x^* if and only if $|f'(x^*)| > 1$ where $x^* = f(x^*)$ (see, for example, Blanchard and Kahn (1980), Grandmont (1986), Woodford (1986), and Chiappori, Geoffard, and Guesnerie (1992)). Thus, equations (16a, b) lead to the following proposition.

Proposition: There exist stationary sunspot equilibria of $\log y^1_t + \log y^2_t$ if and only if

(17) $\gamma < -\mu$ or $\gamma > \mu$.

On the other hand, there exist stationary sunspot equilibria of $\log y^1_t - \log y^2_t$ if and only if

(18) $\gamma < -\mu / (2\alpha - 1)$ or $\gamma > \mu / (2\alpha - 1)$.

The above proposition indicates that there exist stationary sunspot equilibria in our model for two alternative cases. The first is the case where γ is small, that is, the case where the relative risk aversion of the utility function is large. In this case, stationary sunspot

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[10] The transformation follows Aoki (1981) and Fukuda (1993b).

equilibria arise reflecting the conflict between intertemporal substitution and income effects. That is, an expected decline of price levels in future has a negative substitution effect on the current demand for the consumption but has a positive income effect on the current demand for the consumption. Hence, its total effect on the current demand for the consumption is always ambiguous when γ is small, which causes sunspot equilibria that were obtained in the above proposition.

The second is the case where $\mu \equiv (1+\delta)/(\varepsilon+\eta)$ is small, that is, the case where the positive external effects in production are large. In this case, stationary sunspot equilibria arise reflecting strategic complementarity in production. That is, under the strategic complementarity, each agent produces more when he expects more aggregate production but less when he expects less aggregate production. Hence, the total output in the economy depends on whether agents' expectations are bull or bear. This ambiguity also causes sunspot equilibria that were obtained in the above proposition.

However, because $1/2 < \alpha < 1$, it always holds that $\mu/(2\alpha-1) > \mu$. Therefore, the condition (17) is always satisfied if (18) is satisfied, but the condition (18) is not always satisfied even if (17) is satisfied. In other words, stationary sunspot equilibria are more likely outcome for the world aggregate output level, $\log y^1_t + \log y^2_t$, than for the output level difference between two countries, $\log y^1_t - \log y^2_t$. In particular, when $-\mu/(2\alpha-1) < \gamma < -\mu$ or $\mu < \gamma < \mu/(2\alpha-1)$, extraneous uncertainty affects only the world aggregate output level, $\log y^1_t + \log y^2_t$, and causes synchronization of business cycles, that is, international business cycles!

The reason why stationary sunspot equilibria are more likely for the world aggregate output level is that a raise of the expected future output has a positive impact on both domestic and foreign current outputs. In fact, because the condition (17) is equivalent to (18) if $\alpha = 1$, stationary sunspot equilibria are no more likely for the world aggregate output than for country-specific output if there exists no international linkage between two countries.

However, as long as there exists some international linkage between two countries, extraneous uncertainty tends to cause synchronization of business cycles even in the case where the productivity shocks have negative effects on the foreign output, that is, when $\gamma < 0$. In addition, stationary sunspot equilibria are more likely outcome for the world aggregate output level even if the consumption is highly biased to the home product, say, $\alpha = 0.8$.

For example, suppose that $\mu = 3$ and $\alpha = 0.8$. In this case, there exist stationary sunspot equilibria of $\log y^1_t + \log y^2_t$ if $\gamma < -3$. However, there exists no stationary sunspot equilibrium of $\log y^1_t - \log y^2_t$ unless $\gamma < -5$. On the other hand, suppose that $\mu = 0.7$ and $\alpha = 0.8$. In this case, there exist stationary sunspot equilibria of $\log y^1_t + \log y^2_t$ if $\gamma > 0.7$. However, because $\mu/(2\alpha-1) > 1$, there exists no stationary sunspot equilibrium of $\log y^1_t$ -

$\log y^2_t$ for any value of γ.

5. Some Stochastic Simulation Results

The purpose of this section is to present some stochastic simulation results to see how extraneous shocks, that is, sunspots, can cause international business cycles. In the simulation, we first focus on the case where $|\gamma/\mu| > 1 > |\gamma(2\alpha-1)/\mu|$. In this case, there exist sunspot equilibria only for $\log y^1_t + \log y^2_t$. Thus, the general solutions of y^1_t and y^2_t for (12a, b) are written as

$$\text{(19a)} \quad y^1_t = \Gamma \ \exp(q^2/2) \exp(a\, w^1_t) \exp(b\, w^2_t) \ \exp(q\, v_t),$$
$$\text{(19b)} \quad y^2_t = \Gamma \exp(q^2/2) \exp(b\, w^1_t) \exp(a\, w^2_t) \ \exp(q\, v_t),$$

where Γ, a, and b are constant parameters defined by (14a,b,c). In (19a,b), an extraneous stochastic shock v_t follows AR(1) process:

$$\text{(20)} \qquad v_t = (\mu/\gamma)\ v_{t-1} + \varphi_t,$$

where φ_t follows $N(0, 1)$ and is independent over time.

It is easy to see that when $q = 0$, the solutions are reduced to the fundamental values of y^1_t and y^2_t defined by (13a,b). However, to the extent that $|\gamma/\mu| > 1$, q can be chosen arbitrarily even if (19a, b) satisfy (12a, b). Therefore, when the absolute value of q is relatively large, the effects of extraneous shocks can dominate those of fundamental shocks, w^1_t and w^2_t.

Based on (19a,b), we will present stochastic simulation results for some specific parameter sets and stochastic processes. The parameter sets used in the simulation are the following two types:

Type 1: $\alpha = 0.8$, $\rho = 0.9$, $H=1$, $\varepsilon = 0.8$, $\beta = 0.9$, $\delta = 2$, $\eta = 0.2$, $\sigma^2 = 1$, and $\gamma = -4$.
Type 2: $\alpha = 0.8$, $\rho = 0.6$, $H=1$, $\varepsilon = 0.8$, $\beta = 0.9$, $\delta = 0.4$, $\eta = 1.2$, $\sigma^2 = 1$, and $\gamma = 0.8$.

These two parameter sets are the same as those used for figure 1. For stochastic shocks, we assume that all of ξ^1_t, ξ^2_t, and φ_t follow $N(0,1)$ and are independent of each other. We also assume that $y^1_t = y^2_t$ when $t = 0$.

Two graphs in Figure 2a show simulated $\log y^1_t$ and $\log y^2_t$ based on type 1 parameter set for two alternative values of q. That is, Figure 2a-1 is the simulation results for $q = 0$ and Figure 2a-2 is for $q = 1$. Because extraneous shocks have no effect on output levels when $q = 0$, $\log y^1_t$ and $\log y^2_t$ show quite different movements in Figure 2a-1. In particular, because the productivity shocks have negative effects on the foreign output when $\gamma < 0$, $\log y^1_t$ and $\log y^2_t$ have some weak negative correlation in Figure 2a-1. However, when $q = 1$, $\log y^1_t$ and $\log y^2_t$ have strong positive correlation in Figure 2a-2. In particular, because extraneous stochastic v_t has positive serial correlation when $\gamma < 0$, $\log y^1_t$ and $\log y^2_t$ have some negative serial correlation in Figure 2a-2.

Two graphs in Figure 2b, on the other hand, show simulated $\log y^1_t$ and $\log y^2_t$ based on type 2 parameter set for two alternative values of q. That is, Figure 2b-1 is the simulation results for $q = 0$ and Figure 2b-2 is for $q = 5$. Because the productivity shocks have positive effects on the foreign output when $\gamma > 0$, $\log y^1_t$ and $\log y^2_t$ have some weak positive correlation in Figure 2b-1. However, the degree of correlation is small when $q = 0$. On the other hand, when $q = 5$, $\log y^1_t$ and $\log y^2_t$ have strong positive correlation in Figure 2a-2. In particular, because extraneous stochastic v_t has positive serial correlation when $\gamma > 0$, $\log y^1_t$ and $\log y^2_t$ have some positive serial correlation in Figure 2a-2.

Although the above simulation results are based on specific parameter sets, similar results still hold as long as $|\gamma / \mu| > 1 > |\gamma\ (2\alpha - 1) / \mu|$. However, the condition that $|\gamma / \mu| > 1$ is crucial in deriving the results because it is necessary for the existence of sunspot equilibria. In addition, when $|\gamma\ (2\alpha - 1) / \mu| > 1$, there exist sunspot equilibria for both $\log y^1_t + \log y^2_t$ and $\log y^1_t - \log y^2_t$. In this case, the general solutions of y^1_t and y^2_t for (12a, b) are

(21a) $y^1_t = \Gamma \exp[(q^2 + s^2)/2] \exp(a\, w^1_t) \exp(b\, w^2_t) \exp(q\, v_t) \exp(s\, \theta_t)$,

(21b) $y^2_t = \Gamma \exp[(q^2 + s^2)/2] \exp(b\, w^1_t) \exp(a\, w^2_t) \exp(q\, v_t) \exp(-s\, \theta_t)$.

In (21a,b), an extraneous stochastic shock θ_t follows AR(1) process:

(22) $\theta_t = [\mu / \{\gamma\ (2\alpha - 1)\}]\ \theta_{t-1} + \phi_t$,

where ϕ_t follows $N(0, 1)$ and is independent over time. It is easy to see that when $q = s = 0$, the solutions are reduced to the fundamental values of y^A_t and y^B_t. However, to the extent that $|\gamma\ (2\alpha - 1) / (1 + \mu)| > 1$, both q and s can be chosen arbitrarily. When $q \neq 0$ and $s = 0$, extraneous shocks cause only world business cycles again. However, when $s \neq 0$, extraneous shocks may affect each country's output asymmetrically. In particular, when the absolute value of s is relatively large, sunspots do not necessarily make business cycle correlation across countries.

6. The Case of Asymmetric Structure

Until the last section, we have assumed that two countries have the same utility functions and production functions. Although the assumption greatly simplified our analysis, the symmetric economic structure may be restrictive in deriving business cycle correlation across countries. The purpose of this section is to investigate whether introducing asymmetry in production functions may change our basic results or not.

In the following analysis, we assume that the production function in country i (i = 1,2) is written as

$$(23)\quad y^i_t = H_i\, n^{i\ \varepsilon i}_t\, N^{i\ \eta i}_t, \qquad 0 < \varepsilon_i < 1,\ 0 < \eta_i.$$

Except that parameters H_i, ε_i, and η_i are country specific, this production function is essentially the same as what was used in previous sections. For analytical simplicity, we assume that $\varepsilon_1 + \eta_1 \geq \varepsilon_2 + \eta_2$. We also assume that there is no productivity shock, that is, $w^i_t = 0$ for all t.

Under these asymmetric production functions, the dynamic equations (12a,b) are modified as follows

$$(24a)\quad y^{1\ \mu 1}_t = J_1 E_t (y^{1\ \alpha\gamma}_{t+1}\, y^{2\ (1-\alpha)\gamma}_{t+1}),$$
$$(24b)\quad y^{2\ \mu 2}_t = J_2 E_t (y^{1\ (1-\alpha)\gamma}_{t+1}\, y^{2\ \alpha\gamma}_{t+1}),$$

where $J_i \equiv \beta\, \alpha^{\alpha\gamma}(1-\alpha)^{(1-\alpha)\gamma}\, \varepsilon_i H_i^{\mu i}$ and $\mu_i \equiv (1+\delta)/(\varepsilon_i + \eta_i)$.

When there exists no stochastic shock in the economy, these two equations lead to a pair of perfect foresight dynamics for two logged output levels :

$$(25a)\quad \log y^1_t = \log J_1 + (\alpha\gamma/\mu_1) \log y^1_{t+1} + \{(1-\alpha)\gamma/\mu_1\} \log y^2_{t+1},$$
$$(25b)\quad \log y^2_t = \log J_2 + \{(1-\alpha)\gamma/\mu_2\} \log y^1_{t+1} + (\alpha\gamma/\mu_2) \log y^2_{t+1}.$$

The characteristic equation for this two dimensional dynamic system is

$$(26)\quad g(\lambda) \equiv \lambda^2 - \alpha\gamma(\mu_1+\mu_2)/(\mu_1\mu_2)\lambda + (2\alpha - 1)\gamma^2/(\mu_1\mu_2) = 0.$$

It holds that $g(0) > 0$, $g(\alpha\gamma/\mu_1) = g(\alpha\gamma/\mu_2) = -(1-\alpha)\gamma^2/(\mu_1\mu_2) < 0$, and $g(\gamma/\mu_1) = (1-\alpha)\gamma^2(\mu_2-\mu_1)/(\mu_1^2\mu_2) \geq 0$. Thus, the characteristic equation has two characteristic roots λ_1 and λ_2 such that

(27a) $\gamma/\mu_1 \geq \lambda_1 > \alpha\gamma/\mu_1 \geq \alpha\gamma/\mu_2 > \lambda_2 > 0$ when $\gamma > 0$,

(27b) $\gamma/\mu_1 \leq \lambda_1 < \alpha\gamma/\mu_1 \leq \alpha\gamma/\mu_2 < \lambda_2 < 0$ when $\gamma < 0$.

Define $f_1 \equiv (\alpha\gamma - \mu_2\lambda_2)/[(1-\alpha)\gamma] > 0$ and $f_2 \equiv (\mu_1\lambda_1 - \alpha\gamma)/[(1-\alpha)\gamma] > 0$. Then, after some tedious algebra in Appendix, equations (25a, b) are rewritten as

(28a) $\log y^1_t + f_1 \log y^2_t = \text{constant} + \lambda_1 (\log y^1_{t+1} + f_1 \log y^2_{t+1})$,

(28b) $f_2 \log y^1_t - \log y^2_t = \text{constant} + \lambda_2 (f_2 \log y^1_{t+1} - \log y^2_{t+1})$.

When $\mu_1 = \mu_2 \equiv \mu$, it is easy to show that $\lambda_1 = \gamma/\mu$ and $\lambda_2 = (2\alpha - 1)\gamma/\mu$, or equivalently $f_1 = f_2 = 1$. Therefore, as long as $\mu_1 = \mu_2$, introducing asymmetric structure does not change our basic results derived in previous sections. In particular, because $\mu_1 = \mu_2$ even if H_1 is not equal to H_2, we can see that productivity difference between two countries does not change our basic results on international business cycles at all.

However, unless $\mu_1 = \mu_2$, the dynamic property of (28a,b) differs from that of (16a,b). To see this, recall that a one-dimensional map $x_t = f(x_{t+1})$ has sunspot equilibria around its steady state x^* if and only if $|f'(x^*)| > 1$ where $x^* = f(x^*)$. Then, we can derive the following proposition.

Proposition (in case of asymmetric economic structure): There exist stationary sunspot equilibria of $\log y^1_t + f_1 \log y^2_t$ if and only if $|\lambda_1| > 1$. On the other hand, there exist stationary sunspot equilibria of $\log y^1_t - f_2 \log y^2_t$ if and only if $|\lambda_2| > 1$.

Because $|\lambda_1| > \alpha|\gamma|/\mu_1 \geq \alpha|\gamma|/\mu_2 > |\lambda_2|$, $|\lambda_1|$ is always greater than one if $|\lambda_2|$ is greater than one, but $|\lambda_2|$ is not necessarily greater than one even if $|\lambda_1|$ is greater than one. Therefore, stationary sunspot equilibria are more likely for $\log y^1_t + f_1 \log y^2_t$, than for $f_2 \log y^1_t - \log y^2_t$. In particular, when $|\lambda_1| > 1 > |\lambda_2|$ (for example, when $\mu_1 > \alpha|\gamma| > \mu_2$), extraneous uncertainty has an impact only on $\log y^1_t + f_1 \log y^2_t$.

When $|\lambda_1| > 1 > |\lambda_2|$, the general solution of (28a,b) is written as [11]

[11] It holds that $|\lambda_1| > 1 > |\lambda_2|$ if and only if $g(1) < 0$ when $\gamma > 0$ and $g(-1) < 0$ when $\gamma < 0$.

(29a) $\log y^1_t + f_1 \log y^2_t$ = constant + $h\ \zeta_t$,

(29b) $f_2 \log y^1_t - \log y^2_t$ = constant,

or equivalently,

(30a) $\log y^1_t$ = constant + $[1/(1+f_1 f_2)]h\ \zeta_t$,

(30b) $\log y^2_t$ = constant + $[f_2/(1+f_1 f_2)]h\ \zeta_t$.

It is easy to see that an extraneous stochastic shock ζ_t follows AR(1) process:

(31) $\zeta_t = (1/\lambda_1)\ \zeta_{t-1} + \omega_t$,

where ω_t follows $N(0, 1)$ and is independent over time. In addition, because $|\lambda_1| > 1$, a parameter h can be chosen arbitrarily.

Because $1/\mu_1 \geq \lambda_1/\gamma > \alpha/\mu_1$ when $\mu_1 \neq \mu_2$, it holds that $0 < f_2 < 1$ when the production functions have different concavities. Thus, equations (30a,b) indicate that y^1_t can be more volatile than y^2_t when country 1 has a less concave production function than country 2. However, they also imply that even when f_2 is not close to one, an extraneous shock ζ_t moves both y^1_t and y^2_t to the same direction. That is, as long as $|\lambda_1| > 1 > |\lambda_2|$, extraneous shocks can still cause synchronization of business cycles even when two countries do not have the same production functions. Therefore, as long as there exists some international linkage between two countries, extraneous uncertainty is more likely to cause synchronization of business cycles even in the case where production functions are not symmetric between two countries.

7. Concluding Remarks

"Can market psychology matter for world business cycles?" This is the question which we raised throughout this paper. As we showed in the text, the answer to this question is "yes" even in a standard macro model. That is, extraneous shocks can be the source of world business cycles in a standard two-country monetary economy. One noteworthy result in this paper is that as long as there exists some small international linkage between two countries, extraneous uncertainty can cause large synchronization of business cycles. Therefore, even if the fundamental value shows very small cross-country output correlations, changes in market psychology can be one important source of world business cycles.

Throughout the text, we have assumed the cash-in-advance constraints such that agents must set aside home currency in advance to purchase domestic products and foreign currency in advance to purchase foreign products. However, our basic results do not depend on the choice of cash-in-advance constraints, although the existence of cash-in-advance constraints is crucial in deriving sunspot equilibria. This is because money is neutral in standard two country monetary models with cash-in-advance constraints.[12] That is, the choice of cash-in-advance constraints is crucial in determining the equilibrium prices and nominal exchange rates but is not in determining all real equilibrium quantities such as business cycles.

Needless to say, our monetary model is too simple to explain all of characteristics on international business cycles. However, our analysis may be extended to several directions. One possible extension is to introduce capital accumulation in our model. Not a few empirical studies report that correlations of output across countries are larger than those of consumption. The extension may explain this evidence in our monetary model. Another possible extension is to introduce non-traded goods in the model. Since the existence of non-traded goods introduces the possibility of the deviation from the purchasing power parity condition, we may be able to allow the endogenous fluctuations of real exchange rates.

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[12] Of course, money is superneutral in various two country monetary models with cash-in-advance constraints.

Appendix: Derivation of (27a, b) in section 6.

In a matrix form, equations (25a,b) are written as

$$(A1) \qquad \begin{pmatrix} \log y_t^1 \\ \log y_t^2 \end{pmatrix} = \begin{pmatrix} \text{constant} \\ \text{constant} \end{pmatrix} + A \begin{pmatrix} \log y_{t+1}^1 \\ \log y_{t+1}^2 \end{pmatrix}$$

where

$$(A2) \qquad A \equiv \begin{pmatrix} \alpha\gamma / \mu_1 & (1-\alpha)\gamma / \mu_1 \\ (1-\alpha)\gamma / \mu_2 & \alpha\gamma / \mu_2 \end{pmatrix}.$$

Define

$$(A3) \qquad P \equiv \begin{pmatrix} (1-\alpha)\gamma & \mu_2\lambda_2 - \alpha\gamma \\ \mu_1\lambda_1 - \alpha\gamma & (1-\alpha)\gamma \end{pmatrix}.$$

Then, it holds that

$$(A4) \qquad P^{-1}AP = \begin{pmatrix} \lambda_1 & 0 \\ 0 & \lambda 2 \end{pmatrix}$$

where

$$(A5) \qquad P^{-1} = \frac{1}{|P|} \begin{pmatrix} (1-\alpha)\gamma & \alpha\gamma - \mu_2\lambda_2 \\ \alpha\gamma - \mu_1\lambda_1 & (1-\alpha)\gamma \end{pmatrix}.$$

Thus, (A1) can be transformed into

$$(A6) \qquad P^{-1}\begin{pmatrix} \log y_t^1 \\ \log y_t^2 \end{pmatrix} = \begin{pmatrix} \text{constant} \\ \text{constant} \end{pmatrix} + (P^{-1}AP)P^{-1}\begin{pmatrix} \log y_{t+1}^1 \\ \log y_{t+1}^2 \end{pmatrix}$$

$$= \begin{pmatrix} \text{constant} \\ \text{constant} \end{pmatrix} + \begin{pmatrix} \lambda_1 & 0 \\ 0 & \lambda_2 \end{pmatrix} P^{-1}\begin{pmatrix} \log y_{t+1}^1 \\ \log y_{t+1}^2 \end{pmatrix}$$

Therefore, noting that

$$(A7) \qquad P^{-1} = \frac{(1-\alpha)\gamma}{|P|} \begin{pmatrix} 1 & f_1 \\ f_2 & -1 \end{pmatrix},$$

(A6) leads to (27a,b) in the text.

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Figure 1-a Impacts of a Productivity Shock: $\gamma < 0$

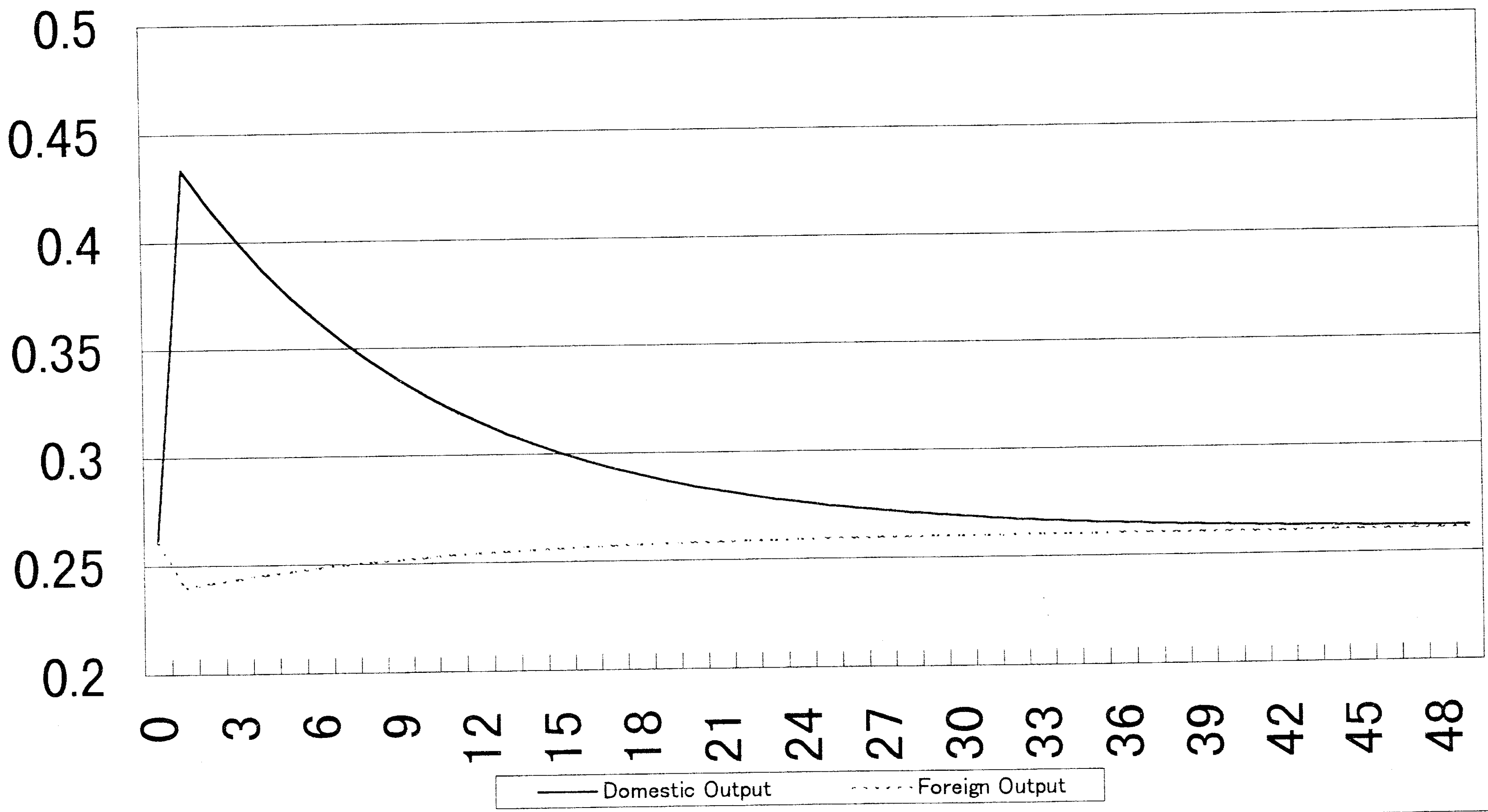


Figure 1-b Impacts of a Productivity Shock: $\gamma > 0$

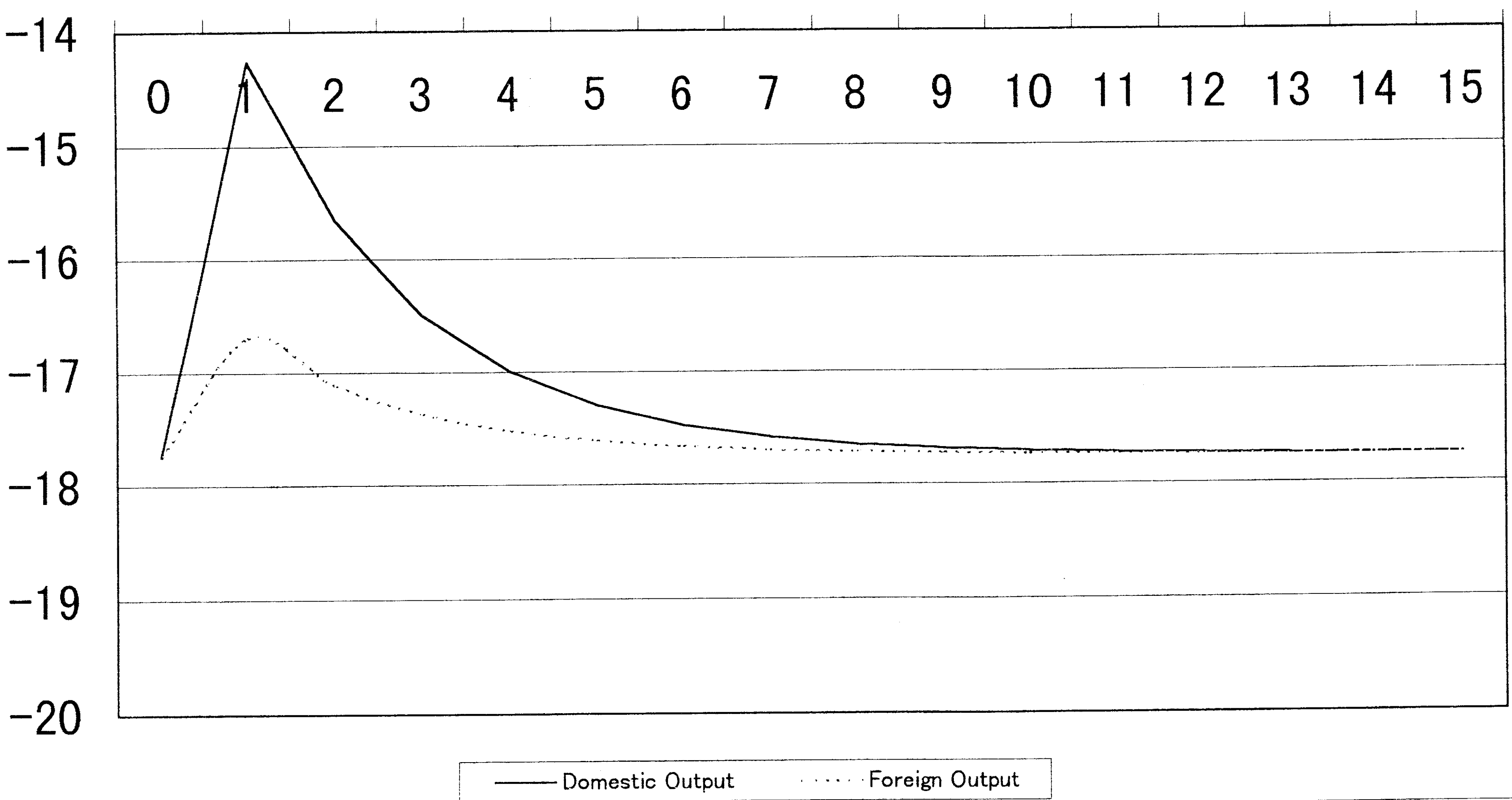
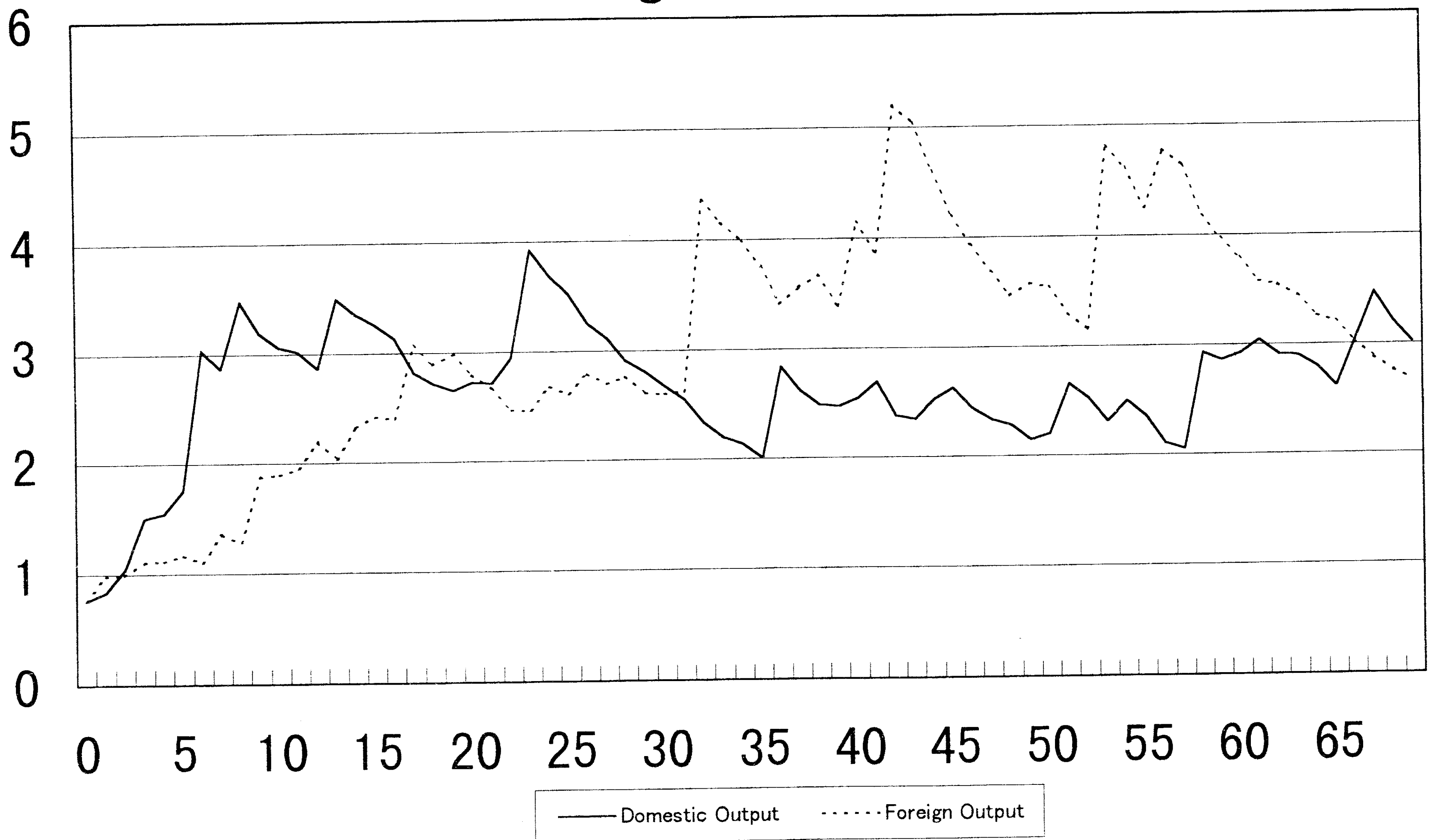


Figure 2a-1



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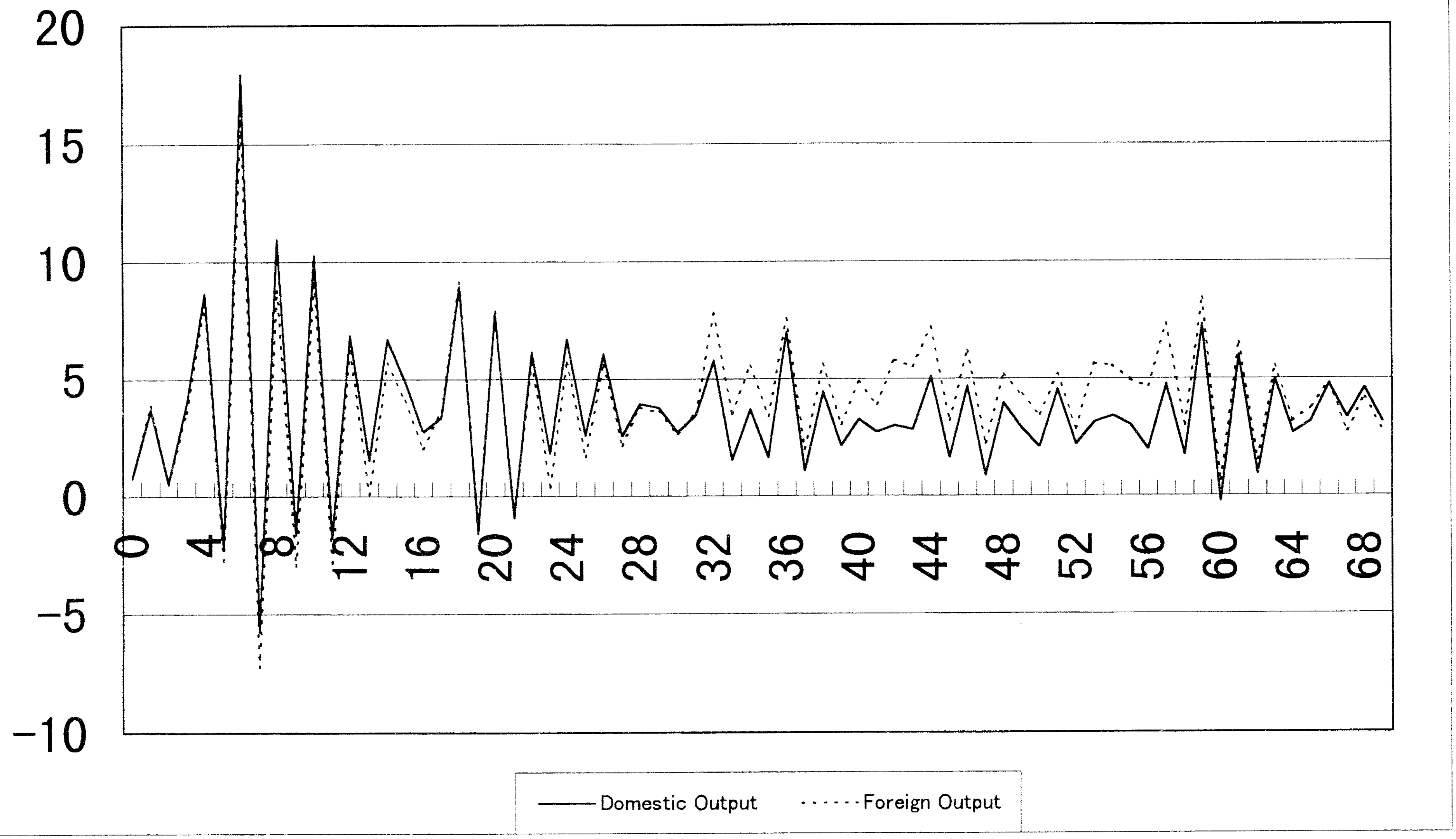
Domestic Output
Foreign Output

Figure 2a-2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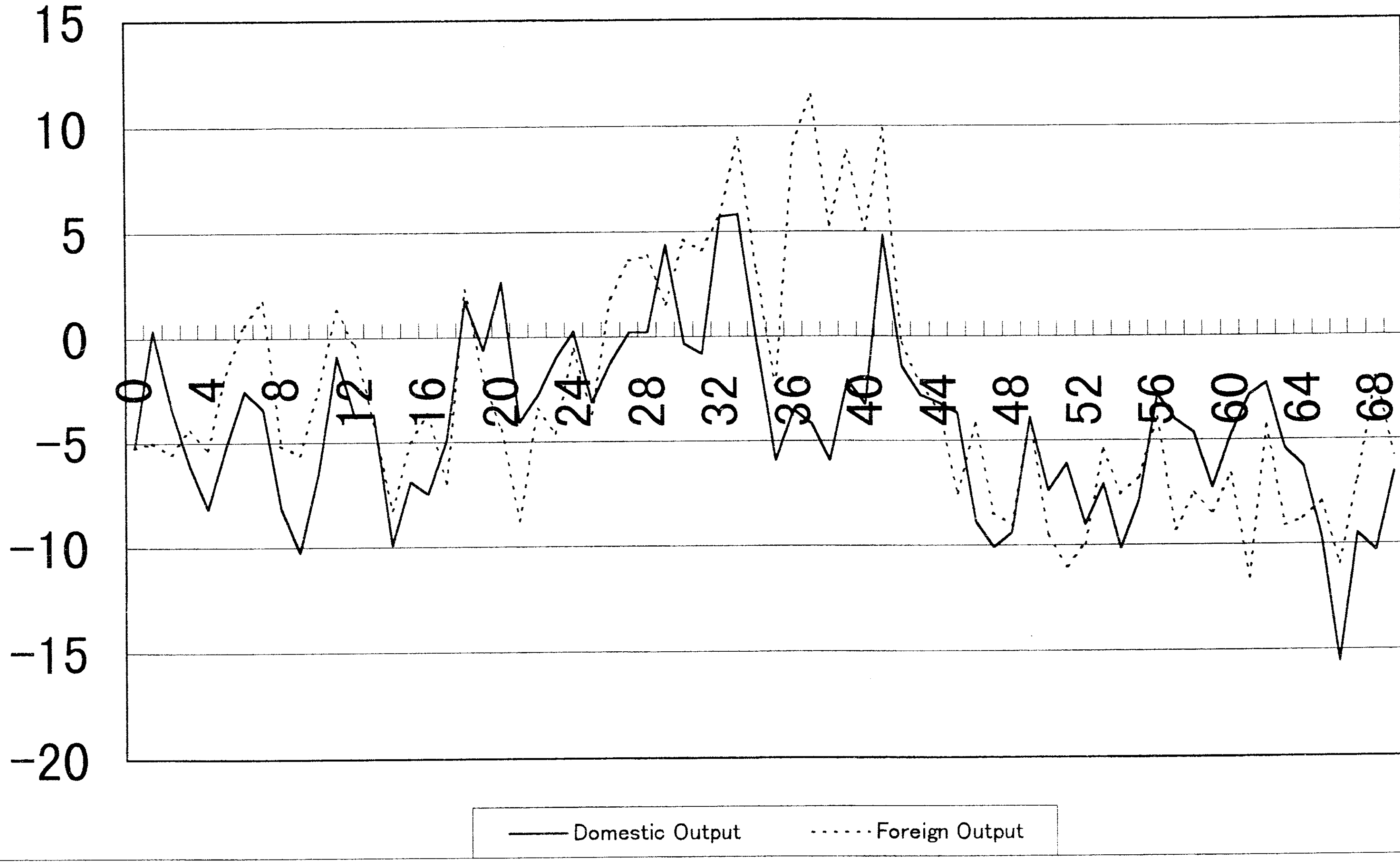
Domestic Output
Foreign Output

Figure 2b-1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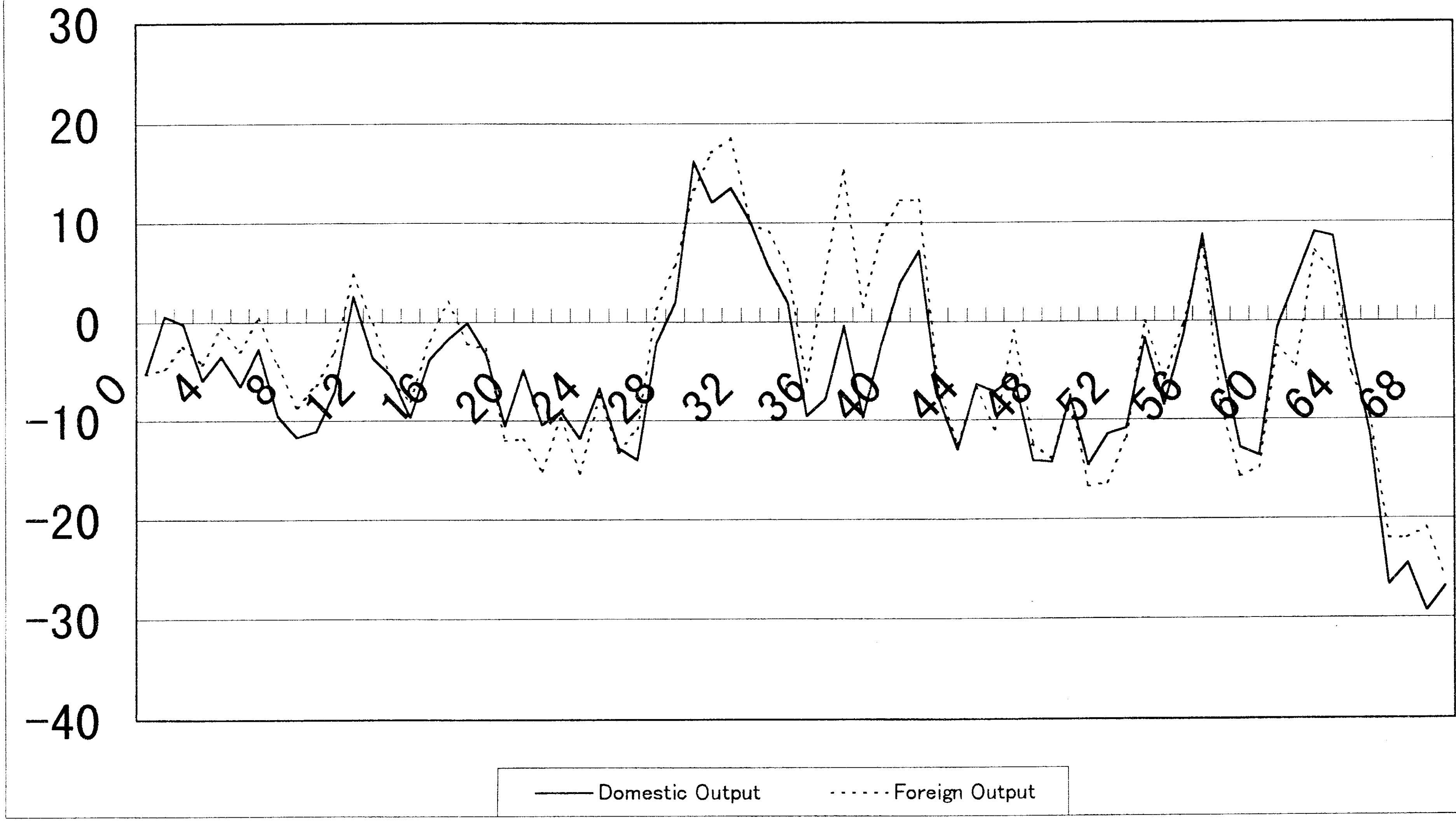
Domestic Output
Foreign Output

Figure 2b-2



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