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Abstract

This paper investigates the changes in local content requirement (LCR) and exchange rate volatility on an international oligopolistic market in a foreign country that accepts n affiliates firms through FDI from a home country. The subordinate firms are forced to procure a proportion of their intermediate products from the foreign firms under the LCR of the foreign government. We derive a Cournot equilibrium of the oligopolistic foreign market, in which affiliate firms compete with the foreign firms under foreign exchange rate uncertainty for when the number of affiliates, n, is either exogenous or endogenous. In the former case, we show the affiliates aggressively expand their outputs and the *ex-post* expected profits of the affiliates decrease but their *ex-ante* certainty equivalent of expected profits increases with the volatility of the exchange rate when the relative risk aversion coefficient is not high at equilibrium. In the latter case, we show LCR tightening from the foreign government always accelerates the exit of the affiliates from the foreign market and if the extent of the relative risk aversion of the international firms is not high, the entry of affiliates onto the foreign market can be urged as the risk of exchange rate increases.

Keywords: risk aversion, exchange rate volatility, local content requirements, FDI, and Cournot oligopoly

JEL classification: G32, L13, L12

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1 Introduction

The bubble of the Japanese economy burst in the early 1990s and the population has been aging and the birthrate declining rapidly thereafter. Consequently, as the domestic markets for various products and services have been shrinking in Japan, manufacturing companies in Japan have been seeking to expand export sales to cover the shortage in their domestic sales. On the other hand, globalization has progressed tremendously since the early 1990s. Competing in cost against their foreign rival manufacturers, Japanese manufacturers have made foreign direct investments (*FDI*).

The host foreign country accepting *FDI* often specifies that at least a certain fraction of inputs must be bought on the local (host foreign) markets, that is, the local content requirement (*LCR*). Under *LCR*, Japanese manufacturers that made *FDI* have to export the rest of their inputs to their affiliates in the foreign country. They also have been remitted part of their profits from their affiliates. As such, they have to face exchange rate uncertainty. From the above, the firms in home country have to choose their outputs on the foreign country's market by using an *ex-ante expectation* of the exchange rate, since they would export a portion of intermediate goods to their affiliates and would receive a part of the remitted.

Here, we consider an international oligopoly model with the oligopolistic market in a foreign country. The international home firms (*IH* firms hereafter) compete on a host foreign country (country 2) oligopolistic market through their affiliates by *FDI*. Assume the government of country 2 imposes LCR on affiliates (*IF* firms hereafter) of at least a δ $(0 < \delta < 1)$ proportion of total inputs. Furthermore, we assume *IF* firm i internally reserves its profit at the foreign market equilibrium at the ratio of s $(0 < s < 1)$ and remits its profit at the ratio of $1 - s$ from the foreign market to the head office of its *IH* firm in the home country. We thus derive a Cournot equilibrium under foreign exchange rate uncertainty for when the number of *IH* firms, n, is either exogenous or endogenous. Then, we explore the effects of foreign exchange rate volatility and the change in the rate of *LCR* on equilibrium outcomes.

2 Model

Assume there are two countries: country 1 (home country) and 2 (foreign country). In country 1's oligopoly, the n international firms of country 1 compete on an oligopolistic market in a host foreign country (country 2) through their affiliate companies by FDI (*IF* firms) with m foreign firms (F firms).

Each *IH* firm in home country 1 has a constant returns to scale technology by $c^H \equiv c_i^{IH}, i = 1, \cdots, n$, indicated by the home currency.

Where an international firm supplies its product on both a domestic market and a foreign market, a domestic firm supplies its product only on a domestic market. Although each *IF* firm procures its parts or intermediate goods from the home country for products on the home country market, it has to procure a δ $(0 < \delta < 1)$ proportion of its parts or intermediate goods from a foreign country for the foreign market as per the LCR of the foreign country government, and procures the rest of parts or intermediate goods from the home country by imports. Each foreign firm supplies its product on the foreign country market and procures all parts or intermediate goods from foreign country 2. We only focus on *the foreign country's market competition* between *IH* and F firms, since *IH* firms choose their outputs for the home country market independently of the outputs for the foreign country's market.

Foreign firms have constant returns to scale technology and their marginal and average common cost is given by $c^F \equiv c_j^F, j = 1, \cdots m$, as indicated by the foreign currency. Each *IF* firm incurs marginal cost $\widetilde{c}^{IF}$ to produce its product in a affiliate company of the foreign country, which is a random variable because it depends on the exchange rate between the home and the foreign country's currencies $\widetilde{\epsilon}$, which is exogenous to the model. $\widetilde{\epsilon}$ is assumed to be a log-normally distributed random variable, that is, $\widetilde{\epsilon} = \exp(\widetilde{X}), \widetilde{X} \sim N(\mu, \sigma^2)$, and we assume that $\sigma^2 > 1$. The foreign Country government stipulates that at least $\delta(0 < \delta < 1)$ of the total inputs have to be bought from the local market and imposes import tariff of $\tau(0 < \tau < 1)$ per unit for import inputs from the home country.

$$\widetilde{c}^{IF} = (1 + \tau)(1 - \delta)c^H/\widetilde{\epsilon} + \delta c^F \tag{1}$$

Then, it is well known that the mean and the variance of $\widetilde{\epsilon}$ are given by

$$\mu_{\widetilde{\epsilon}} = \exp(\mu + \sigma^2/2) \tag{2}$$

and

$$\sigma_{\widetilde{\epsilon}}^2 = \mu_{\widetilde{\epsilon}}^2(e^{\sigma^2} - 1) > \mu_{\widetilde{\epsilon}}^2 \text{ for } \sigma^2 > 1. \tag{3}$$

We can easily derive

$$E_{\widetilde{\epsilon}}[1/\widetilde{\epsilon}] = \exp(-\mu + \sigma^2/2) = \frac{\mu_{\widetilde{\epsilon}}}{e^{2\mu}}, \tag{4}$$

$$Q^F \equiv \sum_{j=1}^{n} q_j^{IF} + \sum_{j=n+1}^{n+m} q_j^F, \tag{5}$$

$$p^F = a^F - \sum_{i=1}^{n} q_i^{IF} - \sum_{j=1}^{m} q_j^F = a^F - Q^{IF} - Q^F, \tag{6}$$

As mentioned in the introduction, the affiliate of each *IH* firm remits a $(1-s)$ portion of its profit to the head office of it in home country 1. Therefore, the head office is interested in the amounts of the expected remittance from its affiliate. Hence, we can define the amounts of remittance to the *IH* firm head office from its affiliate in foreign country 2 as

$$\begin{aligned}\pi_i^{IH} &\equiv (1-s)\widetilde{\epsilon}(p^F - \widetilde{c}^{IF})q_i^{IF} \\ &= (1-s)\widetilde{\epsilon}(a_F - \textstyle\sum_{i=1}^{n} q_i^{IF} - \sum_{j=1}^{m} q_j^F - \widetilde{c}^{IF})q_i^{IF} \\ &= (1-s)\widetilde{\epsilon}(a_F - Q^F - (1+\tau)(1-\delta)c^H/\widetilde{\epsilon} - \delta c^F)q_i^{IF}, i = 1, ..., n. \end{aligned} \tag{7}$$

From (7), (6), and (5), the certainty equivalent of the expected profit of *IH* firm i is given by

$$\begin{aligned} E_{\widetilde{\epsilon}}\left[CE\pi_i^{IH}\right] &= (1-s)E_{\widetilde{\epsilon}}\left[CE\pi_i^{IF}\right] \\ &= (1-s)\{E_{\widetilde{\epsilon}}\left[\widetilde{\epsilon}(p^F - \widetilde{c}^{IF})q_i^{IF}\right] - \gamma SD_{\widetilde{\epsilon}}\left[\widetilde{\epsilon}(p^F - \widetilde{c}^{IF})q_i^{IF}\right]\} \\ &= (1-s)[\mathbf{a}_\epsilon\{a^F - Q^{IF} - Q^F - \delta c^F\} \\ &\quad -(1-\gamma)(1+\tau)(1-\delta)c^H]q_i^{IF}, \end{aligned} \tag{8}$$

where $E(\cdot)$ and $SD(\cdot)$ stand for expectation and standard deviation operators, respectively, and

$$\mathbf{a}_\epsilon = \mu_\varepsilon - \gamma\sigma_\epsilon,$$

where γ is a relative risk averse coefficient. The *IH* firm i chooses q_i^{IF} to maximize the certainty equivalent of *ex-ante* expected profit $E_{\widetilde{\epsilon}}\left[CE\pi_i^{IH}\right]$. Therefore, the first order condition for q_i^{IF} of *IH* firm i is given by

$$\begin{aligned} \frac{\partial E_{\widetilde{\epsilon}}\left[CE\pi_i^{IH}\right]}{\partial q_i^{IF}} &= (1-s)[\mathbf{a}_\epsilon(\mu_\varepsilon, \sigma_\varepsilon)\{a^F - Q^{IF} - Q^F - \delta c^F - q_i^{IF}\} \\ -(1-\gamma)(1+\tau)(1-\delta)c^H] &= 0, i = 1, ..., n. \end{aligned} \tag{9}$$

The profit of foreign firm j is defined by

$$\pi_j^F = (p^F - c^F)q_i^F. \tag{10}$$

From (5) and (10), the first order condition for q_j^F of foreign firm j is given by

$$\frac{\partial \pi_j^F}{\partial q_j^F} = a^F - Q^{IF} - Q^F - c^F - q_j^F = 0,\ j = 1, ..., m. \tag{11}$$

Summing (9) and (11) on i and j, respectively, we obtain

$$(1-s)\mathbf{a}_\epsilon\{na^F - (n+1)Q^{IF} - nQ^F - n\delta c^F\} - (1-s)n(1-\gamma)(1+\tau)(1-\delta)c^H = 0$$

and

$$ma^F - mQ^{IF} - (m+1)Q^F - mc^F = 0.$$

Solving the above two equations w.r.t. Q^{IF} and Q^F, we obtain

$$Q^{*IF} = \frac{n}{m+n+1}\{a^F + (m-(m+1)\delta)c^F - (m+1)(1-\gamma)(1+\tau)(1-\delta)c^H/\mathbf{a}_\epsilon\} \tag{12}$$

and

$$Q^{*F} = \frac{m}{m+n+1}\{a^F - (n+1-n\delta)c^F + n(1-\gamma)(1+\tau)(1-\delta)c^H/\mathbf{a}_\epsilon\}. \tag{13}$$

Since q_i^{IF} and q_j^F are symmetrical in $i = 1, ..., n$ and $j = 1, ..., m$, respectively, from (12) and (13), we get

$$q^{*IF} \equiv q_i^{*IF} = \frac{1}{m+n+1}\left\{a^F + (m-(m+1)\delta)c^F - (m+1)(1-\gamma)(1+\tau)(1-\delta)c^H/\mathbf{a}_\epsilon\right\} \tag{14}$$

and

$$q^{*F} \equiv q_j^{*F} = \frac{1}{m+n+1}\{a^F - (n+1-n\delta)c^F + n(1-\gamma)(1+\tau)(1-\delta)c^H/\mathbf{a}_\epsilon\}. \tag{15}$$

Substituting (12) and (13) into (5), we obtain equilibrium prices on the foreign market:

$$p^{*F} = \frac{1}{m+n+1}\{a^F + (m+n\delta)c^F + n(1-\gamma)(1+\tau)(1-\delta)c^H/\mathbf{a}_\epsilon\}. \quad (16)$$

From (14) (16) and (8), the certainty equivalent of the expected profit of *IH* firm i in the foreign market at equilibrium is given by

$$\begin{aligned} E_{\widetilde{\epsilon}}\left[CE\pi_i^{*IH}\right] &= (1-s)E_{\widetilde{\epsilon}}\left[CE\pi_i^{*IF}\right] = (1-s)\{E_{\widetilde{\epsilon}}\left[\widetilde{\varepsilon}(p^{*F}-\widetilde{c}^{IF})q_i^{*IF}\right] \\ &\quad -\gamma SD_{\widetilde{\epsilon}}\left[\widetilde{\varepsilon}(p^{*F}-\widetilde{c}^{IF})q_i^{*IF}\right]\} \\ &= (1-s)\left[\mathbf{a}_\epsilon\{p^{*F}-\delta c^F\} - (1-\gamma)(1+\tau)(1-\delta)c^H\right]q_i^{*IF} \\ &= \frac{(1-s)\mathbf{a}_\epsilon}{m+n+1}[\{a^F + (m-(m+1)\delta)c^F - n(1-\gamma)(1+\tau)(1-\delta)c^H/\mathbf{a}_\epsilon\}]^2 \\ &= \mathbf{a}_\epsilon(1-s)\left(q^{*IF}\right)^2, \end{aligned} \quad (17)$$

where $\mathbf{a}_\epsilon = \mu_{\widetilde{\epsilon}} - \gamma\sigma_{\widetilde{\epsilon}}$, $\sigma_{\widetilde{\epsilon}}$ and γ stand for the standard deviation of $\widetilde{\epsilon}$ and the relative risk aversion coefficient, respectively. We can interpret $\mathbf{a}_\epsilon$ as *the margin compensation coefficient against the exchange rate risk* since it devaluates the mean of the exchange rate between the home and foreign countries reflecting the relative risk averse of the head office of the *IH* firm from the second line in the first term between the square brackets in (17).

We assume that

$$\mathbf{a}_\epsilon = \mu_{\widetilde{\epsilon}} - \gamma\sigma_{\widetilde{\epsilon}} > 0. \quad (18)$$

From (3), this assumption is equivalent to

$$0 < \gamma < (e^{\sigma^2} - 1)^{-1/2} < 1, \quad (19)$$

since $\mathbf{a}_\epsilon = \mu_{\widetilde{\epsilon}} - \gamma\sigma_{\widetilde{\epsilon}} = \mu_{\widetilde{\epsilon}}(1 - \gamma(e^{\sigma^2}-1)^{-1/2})$.

Hereafter, we assume that

$$(1+\tau)c^H < \mathbf{a}_\epsilon c^F. \quad (20)$$

[1]

Note that the assumption given by inequality (20) implies the marginal cost (or unit cost of inputs) after tax (import tariff) of home country firms is lower than the marginal cost (or unit cost of inputs) of foreign country firms

[1] If (20) does no hold, then *IH* firms would not want to buy intermediate inputs from home country 1 under the exchange rate risk.

compensated by *the margin compensation coefficient against the exchange rate risk.*

The *ex-post* expected profit of *IH* firm i in the home country market at equilibrium is

$$\begin{aligned} E_{\widetilde{\epsilon}}\left[\pi_i^{*IH}\right] &= (1-s)E_{\widetilde{\epsilon}}\left[\pi_i^{*IF}\right] = (1-s)E_{\widetilde{\epsilon}}\left[\widetilde{\varepsilon}(p^{*F}-\widetilde{c}^{IF})q_i^{*IF}\right] \\ &= (1-s)E_{\widetilde{\epsilon}}\left[\widetilde{\varepsilon}(a^F - Q^{*IF} - Q^{*F} - (1+\tau)(1-\delta)c^H/\widetilde{\epsilon} - \delta c^F)q_i^{*IF}\right] \\ &= \frac{(1-s)}{(m+n+1)^2}[\mu_\epsilon(a^F + (m-(m+1)\delta)c^F \\ &\quad + \frac{(1+\tau)(1-\delta)}{\mathbf{a}_\epsilon}c^H(\mu_\epsilon n(1-\gamma) - (m+n+1)\mathbf{a}_\epsilon)] \times \\ &\quad (a^F + (m-(m+1)\delta)c^F - \frac{(m+1)(1-\gamma)(1+\tau)(1-\delta)}{\mathbf{a}_\epsilon}c^H). \end{aligned} \tag{21}$$

The *ex-post* expected profit of firm j in the foreign country market at equilibrium is given by

$$\pi^{*F} = (p^{*F} - c^F)q_j^{*F} = (q_j^{*F})^2. \tag{22}$$

We posit a lemma before presenting results. From (2) and (3), we have

$\frac{\partial\mu_{\widetilde{\epsilon}}}{\partial\sigma^2} = (2e^{\sigma^2}-1)\exp(2\mu+\sigma^2) > 0$ and
$\frac{\partial\sigma^2_{\widetilde{\epsilon}}}{\partial\sigma^2} = \mu_{\widetilde{\epsilon}}(1-\gamma(2e^{\sigma^2}-1)(e^{\sigma^2}-1)^{-1/2})/2 \gtreqless 0 \iff 0 < \gamma \lesseqgtr (e^{\sigma^2}-1)^{1/2}/(2e^{\sigma^2}-1)$.

Furthermore, we can easily show that $(e^{\sigma^2}-1)^{1/2}/(2e^{\sigma^2}-1) < (e^{\sigma^2}-1)^{-1/2} < 1$,

where the last inequality is from (19).

Hence, we immediately obtain the following lemma from the above.

Lemma 1

Assume that $\widetilde{\epsilon}$ is a log-normally distributed random variable, that is, $\widetilde{\epsilon} = \exp(\widetilde{X})$, $\widetilde{X} \sim N(\mu, \sigma^2)$.

Then, we have

$\frac{\partial\mu_{\widetilde{\epsilon}}}{\partial\sigma^2} > 0$, $\frac{\partial\sigma^2_{\widetilde{\epsilon}}}{\partial\sigma^2} \geq (<)\ 0$ *if and only if* $0 < \gamma \leq (e^{\sigma^2}-1)^{1/2}/(2e^{\sigma^2}-1)$
$((e^{\sigma^2}-1)^{1/2}/(2e^{\sigma^2}-1) < \gamma < (e^{\sigma^2}-1)^{-1/2} < 1)$.

Lemma 1 asserts that when the relative risk averse coefficient is small (large), an increase of the exchange rate risk increases (decreases) the mean and variance of the exchange rate.

From (18) and Lemma 1, we can easily derive the next lemma without proof.

Lemma 2
If $0 < \gamma \leq (e^{\sigma^2} - 1)^{1/2}/(2e^{\sigma^2} - 1)$
$((e^{\sigma^2} - 1)^{1/2}/(2e^{\sigma^2} - 1) < \gamma < (e^{\sigma^2} - 1)^{-1/2} < 1)$,
then $\frac{\partial}{\partial \sigma^2}\mathbf{a}_\epsilon \geq 0$ *(* $\frac{\partial}{\partial \sigma^2}\mathbf{a}_\epsilon < 0$*).*

From Lemma 2, an increase in exchange rate risk increases (decreases) the margin compensation coefficient against the exchange rate risk when the relative risk averse coefficient is small (large). The firm with small relative risk for the exchange rate risk does not estimate the margin compensation as too small, but the firm with a large relative risk estimate does so when the exchange rate risk becomes large enough. By using this lemma, we conduct comparative analysis of equilibrium outputs, expected profits of firms and price on the volatility of exchange rate σ^2, and the rate of the stipulation on local contents δ.

3 Comparative Statistics of Equilibrium Outcome

Here, we conduct a comparative analysis on the equilibrium outcome derived above, volatility exchange rate σ^2, and LCR rate δ. We begin with a comparative analysis on exchange rate volatility σ^2. Then, we explore the effect of the rate of the stipulation on local contents δ on the equilibrium outcome.

Before presenting the results, we derive our results as follows.

From (14),(15), (16) and Lemma 2, we have

$$\begin{aligned} \frac{\partial q^{*IF}}{\partial \sigma^2} &= \frac{\partial q^{*IF}}{\partial \mathbf{a}_\epsilon} \cdot \frac{\partial \mathbf{a}_\epsilon}{\partial \sigma^2} \\ &= \frac{(m+1)(1-\gamma)(1+\tau)(1-\delta)}{(m+n+1)\mathbf{a}_\epsilon^2} c^H \cdot \frac{\partial \mathbf{a}_\epsilon}{\partial \sigma^2} \propto \frac{\partial \mathbf{a}_\epsilon}{\partial \sigma^2} \\ &\gtreqless 0 \Leftrightarrow \gamma \lesseqgtr (e^{\sigma^2} - 1)^{1/2}/(2e^{\sigma^2} - 1), \end{aligned} \tag{23}$$

$$
\begin{aligned}
\frac{\partial q^{*F}}{\partial \sigma^2} &= \frac{\partial q^{*F}}{\partial \mathbf{a}_\epsilon} \cdot \frac{\partial \mathbf{a}_\epsilon}{\partial \sigma^2} \\
&= -\frac{n(1-\gamma)(1+\tau)(1-\delta)}{(m+n+1)\mathbf{a}_\epsilon^2} c^H \cdot \frac{\partial \mathbf{a}_\epsilon}{\partial \sigma^2} \propto \frac{\partial \mathbf{a}_\epsilon}{\partial \sigma^2} \\
&\lesseqqgtr 0 \Leftrightarrow \gamma \lesseqqgtr (e^{\sigma^2}-1)^{1/2}/(2e^{\sigma^2}-1), \qquad (24)
\end{aligned}
$$

and

$$
\begin{aligned}
\frac{\partial p^{*F}}{\partial \sigma^2} &= \frac{\partial}{\partial \mathbf{a}_\epsilon} p^{*F} \cdot \frac{\partial}{\partial \sigma^2} \mathbf{a}_\epsilon \\
&= -\frac{n(1-\gamma)(1+\tau)(1-\delta)}{(m+n+1)\mathbf{a}_\epsilon^2} c^H \cdot \frac{\partial \mathbf{a}_\epsilon}{\partial \sigma^2} \propto -\frac{\partial \mathbf{a}_\epsilon}{\partial \sigma^2} \\
&\lesseqqgtr 0 \Leftrightarrow \gamma \lesseqqgtr (e^{\sigma^2}-1)^{1/2}/(2e^{\sigma^2}-1). \qquad (25)
\end{aligned}
$$

Proposition 1
Assume that $a^F + (m-(m+1)\delta)c^F > (m+1)(1-\gamma)(1+\tau)(1-\delta)c^H/\mathbf{a}_\epsilon]$, *(that is,* $q^{*IF} > 0$*). Then, we have*
$\frac{\partial}{\partial \sigma^2} q^{*IF} \geq 0$ (< 0) *if and only if* $0 < \gamma \leq (e^{\sigma^2}-1)^{1/2}/(2e^{\sigma^2}-1)$ $((e^{\sigma^2}-1)^{1/2}/(2e^{\sigma^2}-1) < \gamma < (e^{\sigma^2}-1)^{-1/2} < 1)$,
$\frac{\partial}{\partial \sigma^2} q^{*F} \leq 0$ (> 0) *if and only if* $0 < \gamma \leq (e^{\sigma^2}-1)^{1/2}/(2e^{\sigma^2}-1)$ $((e^{\sigma^2}-1)^{1/2}/(2e^{\sigma^2}-1) < \gamma < (e^{\sigma^2}-1)^{-1/2} < 1)$, *and*
$\frac{\partial}{\partial \sigma^2} p^{*F} \leq 0$ (> 0) *if and only if* $0 < \gamma \leq (e^{\sigma^2}-1)^{1/2}/(2e^{\sigma^2}-1)$ $((e^{\sigma^2}-1)^{1/2}/(2e^{\sigma^2}-1) < \gamma < (e^{\sigma^2}-1)^{-1/2} < 1)$.
Proof: From (23), we obtain the first result.
From (24), we see the second result holds.
From (25), we obtain the third result.

When the relative risk aversion coefficient is not large, if the volatility of the exchange rate increases, then each *IH* firm aggressively expands its output onto a foreign market. Therefore, Q^{*IF} increases enough that the equilibrium price decreases if foreign F firms decrease their outputs q^{*F} to mitigate the fall in price. Hence, Q^{*F} decreases, since they are strategic substitutes in Cournot competition. As the former effect surpasses that of the latter, total equilibrium output $Q^{*IF} + Q^{*F}$ increases and p^{*F} decreases.

Proposition 2
$\frac{\partial}{\partial \sigma^2} E_{\tilde{\epsilon}}[\pi_i^{*IH}] \leq 0$ (> 0) *if and only if* $0 < \gamma \leq (e^{\sigma^2}-1)^{1/2}/(2e^{\sigma^2}-1)$

$((e^{\sigma^2}-1)^{1/2}/(2e^{\sigma^2}-1) < \gamma < (e^{\sigma^2}-1)^{-1/2} < 1)$.
$\frac{\partial}{\partial\sigma^2}E_{\tilde{\epsilon}}[CE\pi_i^{*IH}] \geq 0\ (< 0)$ *if and only if* $0 < \gamma \leq (e^{\sigma^2}-1)^{1/2}/(2e^{\sigma^2}-1)$
$((e^{\sigma^2}-1)^{1/2}/(2e^{\sigma^2}-1) < \gamma < (e^{\sigma^2}-1)^{-1/2} < 1)$.

$\frac{\partial}{\partial\sigma^2}\pi_j^{*F} \leq 0\ (> 0)$ *if and only if* $0 < \gamma \leq (e^{\sigma^2}-1)^{1/2}/(2e^{\sigma^2}-1)$
$((e^{\sigma^2}-1)^{1/2}/(2e^{\sigma^2}-1) < \gamma < (e^{\sigma^2}-1)^{-1/2} < 1)$.
Proof: From (21),we have

$$\begin{aligned}
\frac{\partial}{\partial\sigma^2}E_{\tilde{\epsilon}}[\pi_i^{*IH}] &= \frac{\partial p^{*F}}{\partial\sigma^2}\cdot\mu_{\tilde{\epsilon}}(1-s)q_i^{*F} + \frac{\partial q_i^{*F}}{\partial\sigma^2}(1-s)\mu_{\tilde{\epsilon}}(p^{*F}-\delta c^F) - (1+\tau)(1-\delta)c^H \\
&= \frac{(1-\gamma)(1+\tau)(1-\delta)}{2(m+n+1)\mathbf{a}_\epsilon^2}c^H\mu_{\tilde{\epsilon}}^2(1-s)\{1-\gamma\frac{(2e^{\sigma^2}-1)}{(e^{\sigma^2}-1)^{1/2}}\} \\
&\quad [-(n-1)a^F - (n-1)(m-(m+1)\delta)c^F + \frac{(1+\tau)(1-\delta)c^H}{\mathbf{a}_\epsilon}\times \\
&\quad \{n(m+2)(1-\gamma) - (m+n+1)(1-\gamma(e^{\sigma^2}-1)^{1/2})\}] \lesseqqgtr 0 \Leftrightarrow \\
1-\gamma\frac{(2e^{\sigma^2}-1)}{(e^{\sigma^2}-1)^{1/2}} &\gtreqqless 0 \text{ since } n(m+2)(1-\gamma) - (m+n+1)(1-\gamma(e^{\sigma^2}-1)^{1/2}) \\
&< (m+n+1)(\gamma(e^{\sigma^2}-1)^{1/2}-1) < 0.
\end{aligned}$$

From(17), Lemma 2, and Proposition 1,

$$\begin{aligned}
\frac{\partial}{\partial\sigma^2}E_{\tilde{\epsilon}}\left[CE\pi_i^{*IH}\right] &= \frac{\partial}{\partial\sigma^2}(\mathbf{a}_\epsilon(1-s)\left(q^{*IF}\right)^2) \\
&= (1-s)(\frac{\partial}{\partial\sigma^2}(\mathbf{a}_\epsilon)\left(q^{*IF}\right)^2 + 2\mathbf{a}_\epsilon q^{*IF}\frac{\partial q^{*IF}}{\partial\sigma^2}) \\
&\propto \frac{\partial\mathbf{a}_\epsilon}{\partial\sigma^2} \gtreqqless 0, \text{ so the second statement of the proposition holds.}
\end{aligned}$$

From (22) and Proposition 1, we have

$$\frac{\partial}{\partial\sigma^2}\pi_j^{*F} = 2\frac{\partial}{\partial\sigma^2}q^{*F} \propto \frac{\partial}{\partial\sigma^2}q^{*F} \gtreqqless 0$$

and the third statement follows.■

Note that the result for $\frac{\partial}{\partial\sigma^2}E_{\tilde{\epsilon}}[\pi_i^{*IH}]$ is opposite of the result for $\frac{\partial}{\partial\sigma^2}E_{\tilde{\epsilon}}[CE\pi_i^{*IH}]$ in the above proposition. Therefore, the former (latter) asserts that the expected profit (certainty equivalent of the expected profit) of *IH* firm on the foreign market is non-increasing (non-decreasing) in exchange rate volatility when the relative risk aversion coefficient is not large. In words, the *ex-post* expected profit reacts in quite opposite direction of the *ex-ante* expected profit to the risk of the exchange rate uncertainty.

Next, we explore the effect of the LCR rate δ on the equilibrium outcome.

Proposition 3

If $(e^{\sigma^2}-1)^{-1/2} < \frac{(1+\tau)c^H - \mu_\epsilon c^F}{(1+\tau)c^H - \sigma_\epsilon c^F} < 1$, *then* $\frac{\partial q_i^{*IF}}{\partial \delta} > 0$, $\frac{\partial q_j^{*F}}{\partial \delta} < 0$ *and* $\frac{\partial p^{*F}}{\partial \delta} < 0$ *for* $0 < \gamma < (e^{\sigma^2}-1)^{-1/2} < 1$, *but if* $\frac{(1+\tau)c^H - \mu_\epsilon c^F}{(1+\tau)c^H - \sigma_\epsilon c^F} \le (e^{\sigma^2}-1)^{-1/2} < 1$, *then* $\frac{\partial q_i^{*IF}}{\partial \delta} > 0$, $\frac{\partial q_j^{*F}}{\partial \delta} < 0$ *and* $\frac{\partial p^{*F}}{\partial \delta} < 0$ *for* $0 < \gamma < \frac{(1+\tau)c^H - \mu_\epsilon c^F}{(1+\tau)c^H - \sigma_\epsilon c^F}$, *but* $\frac{\partial q_i^{*IF}}{\partial \delta} \le 0$, $\frac{\partial q_j^{*F}}{\partial \delta} \le 0$ *and* $\frac{\partial p^{*F}}{\partial \delta} \ge 0$ *for* $\frac{(1+\tau)c^H - \mu_\epsilon c^F}{(1+\tau)c^H - \sigma_\epsilon c^F} \le \gamma < (e^{\sigma^2}-1)^{-1/2} < 1$.

Proof: From (14), (15), and (16), we have

$$\begin{aligned}
\frac{\partial q_i^{*IF}}{\partial \delta} &= \frac{\partial}{\partial \delta}\Big(\frac{1}{m+n+1}(a^F + (m-(m+1)\delta)c^F - (m+1)(1-\gamma)(1+\tau)(1-\delta)c^H/\mathbf{a}_\epsilon)\Big) \\
&= -\frac{(m+1)}{\mathbf{a}_\epsilon(m+n+1)}(c^F\mathbf{a}_\epsilon - (1+\tau)(1-\gamma)c^H) \gtreqless 0 \\
&\Leftrightarrow \gamma \lesseqgtr \min\{\frac{(1+\tau)c^H - \mu_\epsilon c^F}{(1+\tau)c^H - \sigma_\epsilon c^F}, (e^{\sigma^2}-1)^{-1/2}\}, \qquad (26)
\end{aligned}$$

$$\begin{aligned}
\frac{\partial q_j^{*F}}{\partial \delta} &= \frac{\partial}{\partial \delta}\left(\frac{1}{m+n+1}(a^F - (n+1-n\delta)c^F + n(1-\gamma)(1+\tau)(1-\delta)c^H/\mathbf{a}_\epsilon)\right) \\
&= \frac{n}{\mathbf{a}_\epsilon}\frac{c^F\mathbf{a}_\epsilon - (1+\tau)(1-\gamma)c^H}{m+n+1} \gtreqless 0 \\
&\Leftrightarrow \gamma \gtreqless \min\{\frac{(1+\tau)c^H - \mu_\epsilon c^F}{(1+\tau)c^H - \sigma_\epsilon c^F}, (e^{\sigma^2}-1)^{-1/2}\}, \qquad (27)
\end{aligned}$$

and

$$\begin{aligned}
\frac{\partial p^{*F}}{\partial \delta} &= \frac{\partial}{\partial \delta}\left(\frac{1}{m+n+1}(a^F + (m+n\delta)c^F + n(1-\gamma)(1+\tau)(1-\delta)c^H/\mathbf{a}_\epsilon)\right) \\
&= \frac{n}{\mathbf{a}_\epsilon}\frac{c^F\mathbf{a}_\epsilon - (1+\tau)(1-\gamma)c^H}{m+n+1} \gtreqless 0 \\
&\Leftrightarrow \gamma \gtreqless \min\{\frac{(1+\tau)c^H - \mu_\epsilon c^F}{(1+\tau)c^H - \sigma_\epsilon c^F}, (e^{\sigma^2}-1)^{-1/2}\}, \qquad (28)
\end{aligned}$$

where the equivalence in the last lines of (26), (27) and (28) follow from (18).

However, from (20), $(1+\tau)c^H < c^H < \mathbf{a}_\epsilon c^F < \mu_\epsilon c^F < \sigma_\epsilon c^F$ since $\mu_\epsilon < \sigma_\epsilon$ from (3).■

Note that $((1+\tau)c^H - \mu_\epsilon c^F)/((1+\tau)c^H - \sigma_\epsilon c^F)$ stands for the ratio of marginal cost (or unit cost of inputs) for foreign country firms evaluated by mean of the exchange rate, $\mu_\epsilon c^F$, over the marginal cost after tax (tariff) of imported inputs from the home country, $(1+\tau)c^H$ to the ratio of marginal cost (or unit cost of inputs) for foreign country firms overvalued by the standard deviation of exchange rate $\sigma_\epsilon c^F$ over the marginal cost after tax (tariff) of imported inputs from the home country, $(1+\tau)c^H$. Then, the above proposition implies that, when this ratio $((1+\tau)c^H - \mu_\epsilon c^F)/((1+\tau)c^H - \sigma_\epsilon c^F)$ is smaller than the upper bound of relative risk aversion coefficient $(e^{\sigma^2}-1)^{-1/2}$ (see assumption1) and if γ is smaller than this ratio, the measure of the relative risk aversion of *IH* firms is not high. As such, the increase of the LCR proportion of the foreign government causes the aggressive expansion of the equilibrium output of the affiliate firm and the defensive decreases of the one of the foreign F firms and the equilibrium price on the foreign market, but if γ is larger than or equal to this ratio, *IH* firms are severely reluctant to the exchange rate risk, and vice versa. However, if this ratio is larger than or equal to the upper bound of relative risk aversion coefficient γ, then the increase in the *LCR* portion of the foreign government increases (decreases) the equilibrium output of the affiliate firm (foreign firm F and equilibrium price) for any γ lower than the upper bound of relative risk aversion coefficient $(e^{\sigma^2}-1)^{-1/2}$.

4 If Number of *IH* Firms is Endogenous

Here, we explore the effects of foreign exchange rate volatility and the change in the proportion of *LCR* on the equilibrium outcomes for when the number of *IH* firms, n, is endogenously determined by the free entry and exit of home country firms onto the foreign market.

We denote by $F > 0$ the entry cost of the *IH* firm of the home country on the foreign market by incorporating its subsidiary companies. The free entry and exit condition onto the foreign market is given as follows:

$$E_{\widetilde{\epsilon}}\left[CE\pi_i^{*IH}\right] = \mathbf{a}_\epsilon(1-s)\left(q^{*IF}\right)^2 = F. \tag{29}$$

From (14), the above equation can be rewritten as

$$\frac{(1-s)\mathbf{a}_\epsilon}{(m+n+1)^2}(a^F+(m-(m+1)\delta)c^F-(m+1)(1-\gamma)(1+\tau)(1-\delta)c^H/\mathbf{a}_\epsilon)^2 = F.$$

Solving this equation with respect to n, we obtain

$$n^* = \sqrt{\frac{\mathbf{a}_\epsilon(1-s)}{F}}(a^F+(m-(m+1)\delta)c^F-(m+1)(1-\gamma)(1+\tau)(1-\delta)c^H/\mathbf{a}_\epsilon)-(m+1).$$

$$\frac{\partial n^*}{\partial \delta} = (m+1)((1-\gamma)(1+\tau)c^H/\mathbf{a}_\epsilon - c^F) \gtreqqless 0 \Leftrightarrow 1-\mathbf{a}_\epsilon c^F/((1+\tau)c^H) \gtreqqless \gamma.$$

However, because $1-\mathbf{a}_\epsilon c^F/((1+\tau)c^H) < 0$, from (20) and $0 < (1+\tau) < 1$,

$$\begin{aligned}\frac{\partial n^*}{\partial \delta} &= (m+1)((1-\gamma)(1+\tau)c^H/\mathbf{a}_\epsilon - c^F) < 0 \\ &\Leftrightarrow 1-\mathbf{a}_\epsilon c^F/((1+\tau)c^H) < 0 < \gamma < (e^{\sigma^2}-1)^{-1/2} < 1.\end{aligned}$$

From Lemma 2,

$$\begin{aligned}\frac{\partial n^*}{\partial \sigma^2} &= \frac{\partial n^*}{\partial \mathbf{a}_\epsilon}\cdot\frac{\partial \mathbf{a}_\epsilon}{\partial \sigma^2} \\ &= \frac{1}{2}\sqrt{\frac{(1-s)}{F\mathbf{a}_\epsilon}}(a^F+(m-(m+1)\delta)c^F+(m+1)(1-\gamma)(1+\tau)(1-\delta)c^H/\mathbf{a}_\epsilon)\cdot\frac{\partial \mathbf{a}_\epsilon}{\partial \sigma^2} \\ &\gtreqqless 0 \Leftrightarrow \frac{\partial}{\partial \sigma^2}\mathbf{a}_\epsilon \gtreqqless 0 \Leftrightarrow \gamma \gtreqqless (e^{\sigma^2}-1)^{1/2}/(2e^{\sigma^2}-1).\end{aligned}$$

Therefore, we present the following proposition without proof.

Proposition 4

$\frac{\partial n^*}{\partial \delta} < 0$ *for any* $0 < \gamma < (e^{\sigma^2}-1)^{-1/2} < 1$.
If $0 < \gamma \leq (e^{\sigma^2}-1)^{1/2}/(2e^{\sigma^2}-1)$
$((e^{\sigma^2}-1)^{1/2}/(2e^{\sigma^2}-1) < \gamma < (e^{\sigma^2}-1)^{-1/2} < 1)$,
then $\frac{\partial n^*}{\partial \sigma^2} \geq 0$ $(\frac{\partial n^*}{\partial \sigma^2} < 0)$.

The above proposition asserts that tightening the LCR of the foreign government always accelerates the exit of affiliate *IF* firms from the foreign market and if the extent of the relative risk aversion of international *IH* firms is not high, the entry of affiliate *IF* firms onto the foreign market can become urged as the exchange rate risk increases.

5 Conclusion

We considered an international oligopoly model with the oligopolistic market in a foreign country. The international home firms (*IH* firms) compete on a host foreign country (country 2) oligopolistic market through their affiliates by *FDI*. Assume the government of country 2 imposes LCR on *IH* firms (or their affiliates) for at least a δ $(0 < \delta < 1)$ proportion of total inputs. Furthermore, we assume *IH* firm i (its affiliate firm) internally reserves its profit at foreign market equilibrium for the ratio of s $(0 < s < 1)$ and remits its profit for the ratio of $1 - s$ from the foreign market to the head office in the home country. We derived a Cournot equilibrium under foreign exchange rate uncertainty for when the number of *IH* firms, n, is either exogenous or endogenous. Then, we explored the effects of foreign exchange rate volatility and change of the rate of *LCR* on equilibrium outcomes.

In the equilibrium for the former case, we show that if the measure of the relative risk aversion of *IH* firms is not high, affiliate firms *IF* aggressively expand their outputs, while the foreign *F* firms defensively decrease their outputs and the equilibrium price on the foreign market. However, if γ is larger than or equal to a certain threshold ratio *IH* firms are severely reluctant to the exchange rate risk, and *vice versa*. Further, the *ex-post* expected profits of the affiliate firms decrease, but their *ex-ante* certainty equivalent of expected profits increases with the volatility of the exchange rate when the relative risk aversion coefficient is not high at equilibrium.

In the latter case, tightening of the LCR from the foreign government always accelerates the exit of affiliate *IF* firms from the foreign market and, if the extent of the relative risk aversion of international *IH* firms is not high, the entry of affiliate *IF* firms onto the foreign market can be urged, as the exchange rate risk increases.

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