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Risk-Averse Multinational Firms and Strategic Trade Policy

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ABSTRACT

We build a three-country model to examine strategic trade policy under uncertainty. A risk-averse MNE (multinational enterprise) engages in horizontal FDI (foreign direct investment) in order to take advantage of local wages and taxes and to avoid global risks. We prove that depending on random shocks' covariance, the MNEs' worldwide production may move in the same or opposite directions. We demonstrate that if the ratio of the variance of shocks in the source and host countries is bounded within an interval, then the MNE will globally diversify its production. We then show that the source country's export tax could possibly increase the MNEs' total outputs. We also prove that if and only if the host country's random shock is more volatile than that in the home country, then the host country's export tax will surely increase the MNEs' overall production. Finally, we obtain that if and only if the covariance of shocks is greater than the variance of shock in the host country, then the source country should use an export tax to raise its national welfare. When the host country's random shock is less volatile than that in the home country, then an export tax is called for to raise the host country's welfare.

Key Words: risk-averter, multinational enterprise, horizontal FDI, strategic trade policy

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1. Introduction

Global foreign direct investment [FDI] has received great attention by trade theorists, because it has maintained an average two-digit growth during the past two decades. The key players, multinational enterprises [MNEs] , have quickly spread their international production around the world. In 2002, sales of MNEs' foreign affiliates amounted to more than 50% of world GDP and the exports of foreign affiliates had a share of more than 33% of world exports.[1] The United Nations (2003) reports, however, that shocks in the global economy resulted in a global downturn of FDI in 2001 and 2002. The exports of MNEs' foreign affiliates may or may not decrease in response to these global shocks. Lipsey (2002) reviews in detail the literature studying the relationship between MNEs' production at home and their affiliates' exports, concluding an indeterminate relationship between these two variables. It is therefore interesting and important to explore how an MNE responds to uncertainty in international markets.

Many shocks are local in nature, but most shocks are internationally and stochastically correlated. As the global economy has become more and more integrated, the correlation between worldwide shocks affects significantly firms' decisions on their production allocation. The lessons from the "Asian crisis" of the late 1990s and SARS' effect last year on the international economy provide exactly such evidence.

As an MNE allocates its production to each geographical plant, national policies become key in attracting FDI and affecting the MNE's decision on production allocation. A source country promoting its national exports should consider not only the subsidy cost of promotion, but also the possibility of hurting its MNEs' profits by crowding out the market shares of the subsidiary abroad. Under these circumstances, a tax, instead of a subsidy, may be required to raise national welfare. On the other hand, a host country attracting FDI needs to take into account its tax revenues from the MNE's subsidiary and how its local firms' profits are affected in any aspects.

The purpose of our paper is to investigate how a multinational enterprise, competing with a rival, allocates its international production under uncertainty. We are especially interested in how random shocks' correla-

1 United Nations (2003) has detailed figures on these issues.

tion among various geographical areas may change a risk-averse firm's decision in the market. We can thereby explore how the source country and the host country may use trade policies to improve national welfare.

Strategic trade policy in the goods market has been well studied ever since the seminal paper of Brander and Spencer (1984, 1985). Under certainty, as proved by Eaton and Grossman (1986), the main theme in the policy implication depends crucially on how firms conduct themselves in the market, either under Cournot or Bertrand competition. In the former case a subsidy on exports is called for and in the latter case a tax is required to raise national welfare. The key device is how a trade policy's strategic effect can be realized. As noted above, firms now use outputs from different plants in the world to compete in the goods market. Except for Ishii (2001), the literature studying strategic trade policy seldom considers this aspect in the model. Using an export cost function, Ishii (2001) obtains a laisser-faire policy when he takes into account the MNEs' overseas production.

It was not until the late-1990s that several contributions were made on the strategic trade policy of a goods market under uncertainty.[2] Qiu (1995) explores a non-linear policy and examines firms' choices of strategic variables under uncertainty. He finds that a non-linear policy can influence the domestic firm's choice of strategic variables and hence alter market conduct in favor of the domestic country. Therefore, a non-linear policy proves strictly superior to a linear one. Grant and Quiggin (1997) adopt a solution concept discussed by Klemperer and Meyer (1989) in which the game's strategy space consists of the class of all price quantity schedules. They derive various optimal trade policies according to different import demand and export supply schedules.

While most research studies under the assumption of uncertainty investigate the trade policy in one market, Anam, Chiang, and Shrestha (1996) demonstrate that stochastically-correlated demand in horizontal markets can be a basis for dumping. In a similar context, Anam and Chiang (2000) further prove that to raise national welfare, a country should tax its exports

2 One expectation is an earlier paper by Cooper and Riezman (1989) who investigate the design of trade policies in an uncertain world. With a sufficient amount of uncertainty, they show that both governments regulate their firms through subsidies.

to the more volatile market while subsidizing them in the other.[3]

Examining an MNE's decision under uncertainty, Das (1983) uses a neoclassical model to show that cost uncertainty prompts the MNE to reduce investment and production in the host country, but has opposite effects on those in the parent country. The demand uncertainty, however, is proved to reduce all the MNE's activities in the world. Our paper is also related to the research literature of tax competition as in Janeba (1998), among others. Janeba (1998) allows firms to move internationally and obtains an optimal free trade policy. However, Janeba does not consider the MNE to globally diversify its production under uncertainty. In deciding an optimal policy, Lai (2002) considers three dimensions, namely the number of instruments available, the location of the market, and the spillovers between firms. He proves that if the MNE's spillovers are very strong, then a country should tax its exports to raise national welfare.

Our paper's contribution has the following dimensions. We examine the strategic trade policy issues in which firms have multi-plants located in different countries. This phenomenon is important in reality, but except for Ishii (2001), few models have touched upon this aspect. Different from Ishii (2001), our model examines the strategic trade policy under uncertainty. Our paper assumes that the MNE appropriates the same production technology to both the parent and subsidiary plants. In a special case our model can generate the same policy implication as Ishii (2001) does. Moreover, in the case of quantity competition we are able to show that an export tax can raise the MNE's global outputs. We find an interesting result that the source country should tax its exports to raise national welfare even in the presence of quantity competition.

From the standpoint of the host country, we obtain a sufficient condition such that the optimal policy is to tax its exports produced by the indigenous and the foreign affiliate. This export tax can collect tax revenues and improve the national welfare. These results are obtained based on a similar structure in the existing literature, e.g., Brander and Spencer (1985). However, by adding uncertainty and overseas production to our model, we arrive at contrasting and important policy implications. Finally, most of

3 Das (1992) considers simultaneous uncertainty in two markets and highlights the impacts of various shocks on the current and future incidence of dumping. Arvan (1991) discusses a tax-subsidy game played between governments. The resulting equilibrium frequently involves asymmetric timing of policy choice.

the existing uncertainty models deal with a trade policy either based on risk-neutral firms (Qiu (1995)) or on two final goods markets (Anam and Chiang (2000)). Our model focuses on the risk-averse MNE with two production bases in two countries.

Our paper follows the spirit of those research papers that assume shocks are stochastically interrelated. We take the perspective, however, that the MNE engages in horizontal FDI and diversifies its worldwide production. The risk-averse MNE uses its home and overseas production to compete with its rival and to dampen the variability of its aggregate profits in the market.

To decide its production allocation, the MNE in our model considers respectively the comparative advantages of the source and host countries. The comparative advantage of a country consists of not only its wage and tax structures, but also how uncertainty is present and how shocks are internationally correlated. When the source country designs its strategic trade policy on its exports, the policy implication depends still on the extent to which the policy may generate a strategic effect. In turn, this depends on how the policy affects the rival's output. Under uncertainty, we will prove that it depends on the variance of shocks and on how international shocks are stochastically correlated.

We find that a risk-averse MNE reduces its home production when the home country imposes an export tax. The MNE, however, may decrease/increase its overseas production to raise its expected utility of profits, depending on how shocks are stochastically correlated. As a result, the MNE's total outputs increase or decrease in response to the tax, and so does its rival's output. When the shocks are stochastically, negatively correlated, a tax on the source country's exports will decrease the MNE's global production. In contrast, when shocks are positively correlated, the source country's export tax always reduces the MNE's home production, but increases its overseas production. In general, if and only if the covariance of shocks is higher than the variance of shock related to the overseas plant, a tax on the source country's exports will increase the MNE's total outputs. In this case, the tax helps reduce the rival's output in the market. Consequently, a tax is called for to raise the source country's welfare.

We let the host country, on the other hand, consider its indigenous firm's profit and tax revenues so as to decide the trade policy. We prove that the host country's optimal trade policy depends on how the export tax affects the MNEs' total outputs in the world. In turn, it depends on the variances of shocks from the two production bases. When the host country's shock is less volatile than that in the source country, the host country's export tax can raise its national welfare; otherwise the tax may prompt the MNE to increase its total output in the world and hurt the indigenous firm's profit. Under these circumstances, the extent to which tax revenues can compensate optimally the profit loss depends on the market shares of the host country's indigenous firm.

Section 2 provides a basic model by which we derive the equilibrium in the goods market under uncertainty. We show how a risk-averse MNE reduces its profit risk by diversifying production around the world. We also demonstrate that by responding to a trade policy, a risk-averse firm may increase its overall production. In Section 3 we explore the optimal trade policy for the source and host countries. Section 4 gives some concluding remarks.

2. The model

As illustrated in Figure 1, we assume that firm 1 in country T engages in horizontal FDI and production. It can use the same technology to produce homogeneous outputs both in the home plant and its subsidiary in country M.[4] Country M has its own firm, firm 2, which competes with firm 1 in a

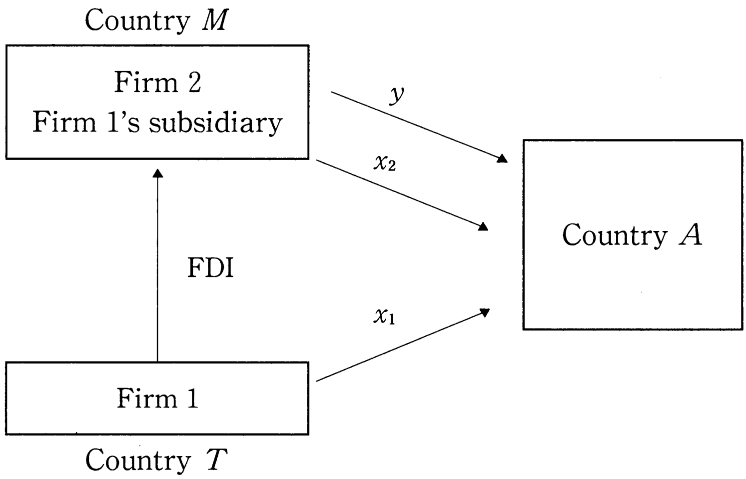

Figure 1. The basic model

4 In our paper, home, parent and source country (plant) are interchangeable.

market in country A. There are two random shocks respectively in countries T and M. The random shocks are country specific, but stochastically correlated. If the shock comes from the supply of an intermediate input required in the production process, then it is a shock from the cost side. If it is the exchange rate shock in the respective countries, then it can be regarded as a demand side shock.

We adopt a three-stage game in the model. In the first stage, governments unilaterally set a tax (or subsidy) on their exports. In the second stage, both firms compete in quantity in the goods market. Firm 1 must decide the output level of its home plant, x_1, and that of its overseas production, x_2, while firm 2 decides its output y. In the final stage, the random shocks are resolved. In order to focus on how a risk-averse MNE uses its home and overseas production to alleviate its profit variability, we assume that firm 1 is risk-averse and firm 2 is risk-neutral. Because we use a subgame perfect equilibrium, we derive backward the equilibrium outcomes.

For tractability, we let the inverse demand function of final goods be of linear form, $P=A-x_1-x_2-y$. The profit functions of both firms are respectively,

$$\pi^1=(A-x_1-x_2-y)(x_1+x_2)-(w_1+e_1+t_1)x_1-(w_2+e_2+t_2)x_2,$$
$$\pi^2=(A-x_1-x_2-y)y-(w_2+e_2+t_2)y.$$

We let e_1 and e_2 represent respectively the random shock in countries T and M. The variables w_i and t_i $i=1,2$ denote respectively country i's wage rate and specific export tax rate (subsidy rate when negative). The random shocks in the profit function are of an additive type. They may represent shocks from the demand or supply side. Hereafter, for simplicity of exhibition, we present it as a cost-side shock. We then specify a mean-variance utility function for both firms.[5]

$$u(\pi^i)=E(\pi^i)-(1/2)R_i[(\pi^i)-E(\pi^i)]^2,\ i=1,2.$$

The constant R_i is a constant absolute risk-aversion index and $E(\ )$ is the mathematical expectation operator. Since firm 2 is risk-neutral and

5 The mean-variance utility function is justified by a bivariate normal distribution of e_1 and e_2. We also need to assume that the firm holds a constant absolute risk-aversion. See Varian (p.189, 1992) for a reference on a case with one random shock. See also Anam and Chiang (2000).

firm 1 is risk-averse, we have $R_1=R>0$ and $R_2=0$. The expected utility of both firms is respectively:

$$Eu(\pi^1)=E(\pi^1)-(1/2)R\sigma^2_{\pi^1}$$
$$=(A-x_1-x_2-y)(x_1+x_2)-(w_1+t_1)x_1-(w_2+t_2)x_2$$
$$-(1/2)R(x_1^2\sigma_1^2+2x_1x_2\sigma_{12}+x_2^2\sigma_2^2), \qquad (1)$$

$$Eu(\pi^2)=(A-x_1-x_2-y)y-(w_2+t_2)y. \qquad (2)$$

The triple-variables (σ_1^2, σ_2^2, σ_{12}) denote respectively the variances and covariance of shocks in countries T and M. The second term of the first equation in (1) represents firm 1's disutility derived from the variance of aggregate profits, $\sigma^2_{\Pi^1}$. This disutility is weighted by a risk aversion index. From the second equation in (1), we can see that the variance of aggregate profits is a weighted sum of the variances and covariance of shocks in both countries, with home and overseas quantities of output as weights. The MNE must decide simultaneously the production allocation (x_1, x_2). By (1), the optimal allocation must balance by maximizing the expected profit and minimizing the variance of profit. The first-order condition for both firms' maximization of $Eu(\pi^i)$ is respectively:

$$\partial Eu(\pi^1)/\partial x_1=A-2x_1-2x_2-y-(w_1+t_1)-R(\sigma_1^2x_1+\sigma_{12}x_2)$$
$$=A-(2+R\sigma_1^2)x_1-(2+R\sigma_{12})x_2-y-(w_1+t_1)=0, \qquad (3)$$
$$\partial Eu(\pi^1)/\partial x_2=A-2x_1-2x_2-y-(w_2+t_2)-R(\sigma_2^2x_2+\sigma_{12}x_1)$$
$$=A-(2+R\sigma_{12})x_1-(2+R\sigma_2^2)x_2-y-(w_2+t_2)=0, \qquad (4)$$
$$\partial Eu(\pi^2)/\partial y=A-x_1-x_2-2y-(w_2+t_2)=0. \qquad (5)$$

In view of the first equation in (3) and (4) respectively, they equate the expected marginal revenue to the risk-inclusive marginal cost. The risk-inclusive marginal cost consists of wage and export tax and the marginal disutility derived from the variance of aggregate profits. This marginal disutility, however, may be positive or negative, depending on the variance-covariance of shocks and output levels. In this regard, the MNE's marginal costs of home and overseas production are essentially inter-related. This marginal cost's interdependence hinges on the correlation of random shocks. Whenever the marginal disutility is positive, the uncertainty will prompt the risk-averse firm to set lower production output levels x_1 and x_2 than a risk-neutral firm does (where $R=0$).

The uncertainty also brings in an additional aspect to consider the optimal allocation of outputs. By (3) and (4) we can see that given its rival's output y, an increase in the production $x_i (i=1, 2)$ need not necessarily decrease the production of $x_j (j=1, 2, j \neq i)$. This reciprocal relationship depends on how random shocks are stochastically, positively or negatively correlated. When shocks are stochastically, negatively correlated, they provide a built-in device in which the randomness of both country shocks reduces the variance of aggregate profits. By (3), an increase in the MNE's overseas production x_2 reduces directly the MNE's expected marginal profit of home production x_1. It also reduces indirectly the variance of the MNE's profits when shocks are "negatively" correlated. If this latter effect is strong enough to outweigh the former, then in response to an increase in x_2 the MNE will increase home production x_1.

The sign of $(2+R\sigma_{12})$ in the second equation of (3) shows the magnitude of the two forces' net effect. A similar argument can be applied to equation (4). Depending on the sign of $(2+R\sigma_{12})$, an increase in home production x_1 may encourage or discourage the MNE's overseas production x_2.

We assume that the second-order conditions of both firms' maximization of $Eu(\pi^i)$ are satisfied by the following conditions:

$$\partial^2 Eu(\pi^1)/\partial x_1^2 = -(2+R\sigma_1^2) < 0$$

$$\partial^2 Eu(\pi^1)/\partial x_2^2 = -(2+R\sigma_2^2) < 0$$

$$\partial^2 Eu(\pi^1)/\partial x_1 \partial x_2 = -(2+R\sigma_{12}) = \partial^2 Eu(\pi^1)/\partial x_2 \partial x_1,$$

$$\Omega \equiv \begin{vmatrix} \partial^2 Eu(\pi^1)/\partial x_1^2 & \partial^2 Eu(\pi^1)/\partial x_1 \partial x_2 \\ \partial^2 Eu(\pi^1)/\partial x_2 \partial x_1 & \partial^2 Eu(\pi^1)/\partial x_2^2 \end{vmatrix} = (2+R\sigma_1^2)\,(2+R\sigma_2^2) - (2+R\sigma_{12})^2 > 0,$$

$$\partial^2 Eu(\pi^2)/\partial y^2 = -2 < 0.$$ [6]

We solve respectively (3), (4), and (5) and obtain

$$A-(3+2R\sigma_1^2)x_1-(3+2R\sigma_{12})x_2-2(w_1+t_1)+(w_2+t_2)=0, \tag{6}$$

$$A-(3+2R\sigma_{12})x_1-(3+2R\sigma_2^2)x_2-(w_2+t_2)=0. \tag{7}$$

Equations (6) and (7) tell how the MNE's home and overseas production should be decided in the equilibrium. By (6) and (7), we see that whether or not an increase in the home (overseas) production encourages overseas

6 Let the variable ρ denote the constant correlation coefficient of the two random shocks (e_1, e_2). In Appendix A we prove that if the inequality condition $R\sigma_1\sigma_2(1-\rho) > 4$ holds, then the second-order condition is satisfied.

(home) production depends on the sign of $3+2R\sigma_{12}$. As noted above, this term denotes the net effect of two forces in considering the relationship of home and overseas production. It especially takes into account firm 2's optimal decision.

Since the sign of $3+2R\sigma_{12}$ is crucial in deciding a country's optimal trade policy, it deserves further explanation. For instance, an increase in the overseas production x_2 may decrease directly the marginal expected profit of x_1, but may also affect indirectly the expected disutility from the variance of aggregate profits. In particular, if the covariance σ_{12} is positive (negative), then it increases (reduces) the MNE's marginal disutility on x_1. Therefore, whenever $3+2R\sigma_{12}$ is positive, it means that the direct effect is either stronger than or has the same qualitative impact as the indirect effect. As a result, the increase in one geographical plant's output always prompts the MNE to decrease the other plant's output. On the other hand, if $(3+2R\sigma_{12})$ is negative, then the random shocks must be negatively correlated, meaning that the direct effect of an increase in the overseas production is weaker than its indirect effect of reducing the expected disutility. In this case, responding to an increase in one geographical output, the MNE will also raise the other plant's outputs.

We depict the locus of equations (6) and (7) as the ll and kk curves, respectively, in Figures 2 and 3. Applying respectively the Implicit Function Theorem to (6) and (7), we can have the slope of both curves in Figures 2 and 3.

$$dx_2/dx_1|_{ll}=-(3+2R\sigma_1^2)/(3+2R\sigma_{12})\gtrless 0,$$
$$dx_2/dx_1|_{kk}=-(3+2R\sigma_{12})/(3+2R\sigma_2^2)\gtrless 0,$$

In Figure 2 under the condition that $3+2R\sigma_{12}>0$ holds, both equations (6) and (7) have a negative slope. In contrast, in Figure 3 the condition $3+2R\sigma_{12}<0$ holds and both curves have a positive slope.

In Appendix B we prove that the second-order condition of the MNE's maximization of $Eu(\pi)$ is sufficient to assure that the slope of (6) is greater in the absolute sense than that of (7). We now solve (6) and (7) simultaneously and in Appendix C we obtain the equilibrium outputs in the goods market:

$$x_1=(1/\Delta)\{2R(\sigma_2^2-\sigma_{12})A-2(3+2R\sigma_2^2)(w_1+t_1)+2[3+R(\sigma_2^2+\sigma_{12})](w_2+t_2)\}, \quad (8)$$

$$x_2=(1/\Delta)\{2R(\sigma_1^2-\sigma_{12})A-2[3+R(\sigma_1^2+\sigma_{12})](w_2+t_2)+2(3+2R\sigma_{12})(w_1+t_1)\}, \quad (9)$$

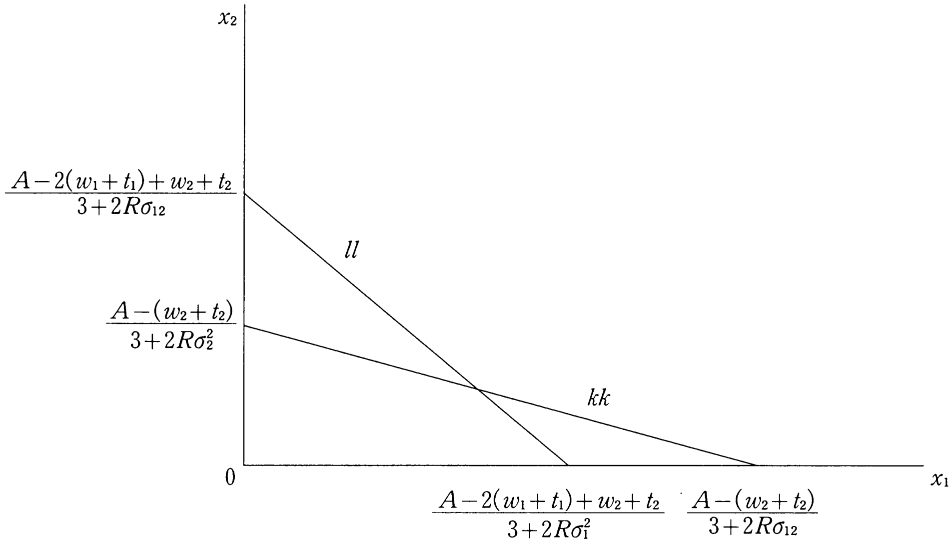

Figure 2. $3+2R\sigma_{12}>0$

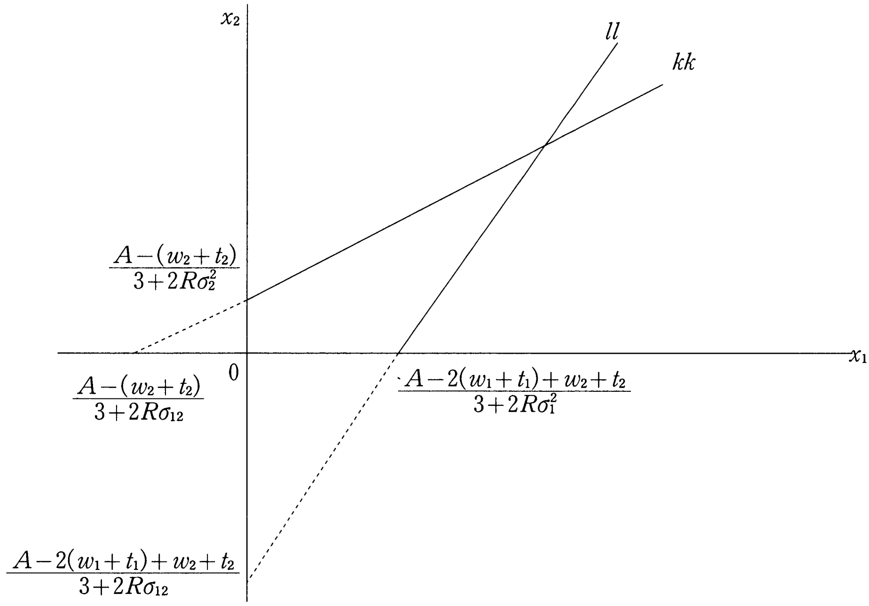

Figure 3. $3+2R\sigma_{12}<0$

where $\Delta \equiv (3+2R\sigma_1^2)(3+2R\sigma_2^2)-(3+2R\sigma_{12})^2>0$.

The sufficient and necessary condition for the MNE to globally diversify its production can be obtained by (8) and (9). These conditions include the local advantage of wages and taxes. They also consist of risks between countries. By (6) and (7), one can see that if the MNE is risk-neutral ($R=0$) and the source country owns a local advantage in production, i.e., $t_1+w_1<t_2+w_2$, then firm 1 will not allocate any production to its subsidiary. In contrast, if the MNE is risk-averse and both countries have the same local production advantage, i.e., $w_1+t_1=w_2+t_2$, then it is still possible that the presence of uncertainty prompts risk-averse firm 1 to diversify its risk by allocating production to both countries. We obtain the following proposition regarding the MNE's incentive to diversify its production in an uncertain world.

Proposition 1: Assume that the source and host countries have the same wage and tariff structure, i.e., $w_1+t_1=w_2+t_2$. If the ratio of variances of the home and host countries' shocks is bounded by an interval $\rho<\sigma_1/\sigma_2<1/\rho$, then the risk-averse MNE will globally diversify its production.

Assuming both countries hold the same location advantage on wages and taxes, Proposition 1 presents the incentive of risk-diversification for the MNE to engage in the FDI. The result in Proposition 1 can be calculated by (8) and (9). When the condition $w_1+t_1=w_2+t_2$ holds, we have $x_1=2R(\sigma_2^2-\sigma_{12})(A-w_1-t_1)/\Delta$ and $x_2=2R(\sigma_1^2-\sigma_{12})(A-w_1-t_1)/\Delta$. It follows immediately that the home production is greater, less than, or equal to the overseas production if and only if σ_2^2 is greater, less than, or equal to σ_1^2. Therefore, the MNE always allocates more output to the less risky country than to the more volatile country.

It also follows that both outputs are positive if the conditions $\sigma_2^2>\sigma_{12}$ and $\sigma_1^2>\sigma_{12}$ hold. These inequalities are equivalent to $\rho<\sigma_1/\sigma_2<1/\rho$. Intuitively, a relatively high variance of shock for the home country is necessary to allocate some production to the host country. On the other hand, a relatively high variance of shock in the host country prompts the MNE to allocate some production at home. As noted above, the stochastic correlation between shocks plays a crucial role in deciding the output allocation.

Proposition 1 tells us exactly the possible range of random shock's variances and the correlation coefficient, within which the MNE's production diversification is optimal. In Figure 2 we can further see that given random shocks' covariance σ_{12}, a high risk in the host country rotates the *kk* curve upward. The MNE reduces the production abroad, but adds more production at home. In contrast, a reverse result occurs when σ_1^2 increases. In order to have an interior solution we see that the conditions $\sigma_2^2 > \sigma_{12}$ and $\sigma_1^2 > \sigma_{12}$ must hold.

Assume again that both countries have the same local production advantage. By (8) and (9), we can see that when random shocks are stochastically, negatively correlated or not correlated at all, the existence of uncertainty itself is enough for firm 1 to diversify its international production. This finding can be justified by viewing Figure 3 in which the random shocks are stochastically, negatively correlated.

Let us now report the comparative static analysis with respect to the trade policy of the source and host countries. We have

$$
\begin{aligned}
dx_1/dt_1 &= (1/\Delta)\,[-2(3+2R\sigma_2^2)] < 0,\\
dx_1/dt_2 &= (1/\Delta)\,[6+2R(\sigma_2^2+\sigma_{12})] \gtrless 0,\\
dx_2/dt_1 &= (1/\Delta)\,[2(3+2R\sigma_{12})] \gtrless 0,\\
dx_2/dt_2 &= (-1/\Delta)\,[6+2R(\sigma_1^2+\sigma_{12})] \gtrless 0,\\
d(x_1+x_2)/dt_1 &= (1/\Delta)\,(-6-4R\sigma_2^2+6+4R\sigma_{12})\\
&= (-4R)\,(\sigma_2^2-\sigma_{12})/\Delta \gtrless 0,\\
d(x_1+x_2)/dt_2 &= (1/\Delta)\,(6+2R\sigma_2^2+2R\sigma_{12}-6-2R\sigma_1^2-2R\sigma_{12})\\
&= (2R/\Delta)\,(\sigma_2^2-\sigma_1^2) \gtrless 0.
\end{aligned} \tag{10}
$$

We summarize our results of the comparative static analysis in the following two propositions.

Proposition 2: (1) The source country's export tax will reduce the MNE's home production, but may increase or decrease its overseas production, depending on whether or not the condition $3+2R\sigma_{12} > (<) 0$ holds. (2) If and only if $\sigma_{12} > \sigma_2^2$, then the source country's export tax will increase the MNE's overall production in the equilibrium.

By the first, third, and fifth equations in (10), those results in Proposition 2 can be clearly derived. The fact that an export tax reduces the MNE's home production is not surprising. However, the result that it may increase the MNE's overall production is striking. According to equation

(6), an increase in the source country's export tax decreases directly the MNE's marginal expected utility on the home production, x_1. Therefore, the home production is reduced. However, this reduction in the home production may affect the risk-inclusive marginal cost of the overseas production x_2. Consequently, the MNE's marginal expected utility on the overseas production might increase or decrease, depending on the sign of $3+2R\sigma_{12}$. In view of Figure 2, where $3+2R\sigma_{12}$ is positive, the tax shifts the ll curve inward, but keeps the kk curve intact. As a result, the MNE decreases the home production and increases its overseas production.

The economic intuition behind the result is as follows. When shocks are positively correlated (or negatively correlated with $3+2R\sigma_{12}>0$), the decrease in home production raises the marginal expected profit and reduces (increases) the marginal disutility on the overseas production. The net effect is always to raise the overseas production. However, the extent to which the MNE's overseas production increases depends on the slope of the kk curve. The slope of the kk curve tells how the overseas production should respond to the decrease in home production. According to (7), it depends on the relative magnitude of random shocks' covariance σ_{12} and the variance of country M's shock σ_2^2. When the covariance is greater than the variance of country M's shock, then a one-unit decrease in the home production will prompt the MNE to increase more than one unit in its overseas production. Consequently, the home country's export tax not only increases the MNE's overseas production, but also the MNE's overall production.

When shocks are negatively correlated such that the condition $3+2R\sigma_{12}<0$ holds, then the source country's export tax shifts the ll curve to the left and decreases both home and overseas production. Intuitively, when shocks are negatively correlated, the decrease in the home production both increases the marginal expected profit and the marginal disutility on the overseas production. The former impact encourages the MNE to raise overseas production. The latter then discourages the MNE to lower it. If the condition $3+2R\sigma_{12}<0$ holds, then it means that the latter effect will dominate the former. Consequently, overseas production will also decrease, and so will the MNE's overall production.

By (10), we also have the following proposition regarding the host country's policy effects on our model.

Proposition 3: (1) If random shocks are stochastically, positively cor-

related, then the host country's export tax will increase the MNE's home production, but will decrease its overseas production. (2) When random shocks are stochastically, negatively correlated, the host country's export tax effect may have any sign on the MNE's home and overseas production. (3) If and only if the host country's shock is more volatile than that in the home country, i.e., $\sigma_2 > \sigma_1$, then the host country's export tax will increase the MNE's overall production.

We can use the second, fourth, and the sixth equations in (10) to derive those results in Proposition 3. The host country's tax policy on the MNE's decision is more complex than that in Proposition 2. In view of Figure 2 with $3+2R\sigma_{12}>0$, we can see that an increase in the host country's export tax shifts the *ll* curve outward, but shifts down the *kk* curve. Therefore, the home production increases unambiguously and the overseas production decreases.

According to (7), we can see that the host country's export tax decreases directly the marginal expected utility on the overseas production. The MNE therefore has an incentive to reduce the overseas production. When shocks are stochastically correlated such that the condition $3+2R\sigma_{12}>0$ holds, this overseas production deduction will prompt the MNE to raise its home output. Moreover, according to (6), the host country's export tax also directly increases the marginal expected utility on the home production. Consequently, it pushes further up the home production.

In Figure 3 with $3+2R\sigma_{12}<0$, we see by contrast that the export tax shifts both the *ll* and *kk* curves to the right. We therefore cannot pin down the tax's impact on these respective outputs. The host country's export tax directly discourages the overseas production. When shocks are negatively correlated such that the condition $3+2R\sigma_{12}<0$ holds, the deduction in the overseas production has stronger impacts on the MNE's disutility than on the expected profit of home production. Hence, this overseas production deduction gives incentives for the MNE to reduce the home production.

By (6) one notices that the host country's export tax raises directly the marginal expected utility on the home production. It thereby encourages the MNE to increase the home production. These two forces are contradicting. That is why when the condition $3+2R\sigma_{12}<0$ holds, we cannot pin down the host country's tax impacts on the MNE's outputs.

The final part of Proposition 3 proves that if the host country is more volatile than the home country, then without referring to the sign of $3+2R\sigma_{12}$ the MNE's overall output will increase in response to the host country's export tax. According to the second equation and the fourth equation of (10), the magnitude of changes in both outputs depends crucially on the variances and covariance of shocks in both countries. In the case with $3+2R\sigma_{12}>0$, we can infer that a high variance of shock abroad, relative to that at home, prompts the MNE to trade off more the home production expansion for the overseas production. Therefore, the overall output increases. In the case with $3+2R\sigma_{12}<0$, the host country's tax impacts on the home and overseas production are not clear. We can only refer to the sixth equation in (10) and see that the tax's net effect on the MNE's global output hinges on the relative magnitude of variances across countries.

From (5) we can derive a trade policy's impact on firm 2's output. We differentiate firm 2's output y with respect to t_1 and t_2. We then obtain

$$dy/dt_1=[\partial y/\partial(x_1+x_2)]\,[d(x_1+x_2)/dt_1]=2R(\sigma_2^2-\sigma_{12})/\Delta, \quad (11)$$

$$\begin{aligned} dy/dt_2&=[\partial y/\partial(x_1+x_2)]\,[d(x_1+x_2)/dt_2]+\partial y/\partial t_2 \\ &=(-1/2)\,(2R/\Delta)\,(\sigma_2^2-\sigma_1^2)-1/2. \end{aligned} \quad (12)$$

We summarize our findings in the following proposition regarding the trade policy's effect on firm 2's output.

Proposition 4: (1) If and only if $\sigma_{12}>\sigma_2^2$, then the source country's export tax will decrease firm 2's output y. (2) If the host country's shock is more volatile than that in the home country, i.e., $\sigma_2>\sigma_1$, then the host country's export tax will decrease firm 2's output y.

From equation (5) one can see that an increase in the MNE's overall production moves in the opposite direction with firm 2's output y. Therefore, the result in Proposition 4 is an extension of the previous results. It is worth noting that when firms compete in quantity, an export subsidy always reduces its rival's output in the certainty models.[7] Under uncertainty, the first part of Proposition 4 says that the source country's export tax may reduce the home production as the existing literature does, but under some conditions it is the export tax to reduce the rival's output.

7 See Brander and Spencer (1985) for a good example.

Our model allows the MNE to increase its subsidiary output in response to the tax. Through the tax, the MNE obtains a higher market share than the one without the tax. On the other hand, from (5) we see that the host country's export tax directly reduces the marginal expected utility on firm 2's output y. Using the third part in Proposition 3, we learn that if and only if the host country's random shock is more volatile than that in the home country, then the host country's export tax increases the MNE's global output.

In turn, from (5) we see that the MNE's output affects adversely firm 2's output y. We therefore have the second part of Proposition 2. According to (12), however, we see that the host country's export tax may be possible to increase firm 2's output y if the host country's shock is "less" volatile than that in the home country. All these fruitful findings have significant implications on a country's optimal trade policy in the next section.

3. The optimal trade policy

3.1 The source country's optimal policy

Let the social welfare function of country T be firm 1's expected profit plus the tax revenues, i.e.,

$$W^1 = Eu(\pi^1) + t_1 x_1.$$

Differentiating the social welfare function with respect to the specific tax rate t_1 and using (3) and (4), we have

$$\begin{aligned} dW^1/dt_1 &= (\partial Eu(\pi^1)/\partial x_1)(dx_1/dt_1) + (\partial Eu(\pi^1)/\partial x_2)(dx_2/dt_1) \\ &\quad + (\partial Eu(\pi^1)/\partial y)(dy/dt_1) + \partial Eu(\pi^1)/\partial t_1 + x_1 + t_1 dx_1/dt_1 \\ &= -(x_1+x_2)(dy/dt_1) + t_1 dx_1/dt_1. \end{aligned} \tag{13}$$

The second equation in (13) is mainly obtained by (3) and (4). The third term in the first equation of (13) denotes the well-known strategic effect of the export tax. Its sign depends crucially on how firm 2's output y is affected by the tax. Notice that the second-order condition is automatically satisfied.[8] Consequently, the social welfare function is strictly concave in the export tax rate t_1. Equating (13) to zero, we have the optimal trade policy for country T:

8 Using (10) and (11), we have $d(W^1)^2/dt_1^2 = -(dy/dt_1)\, d\,(x_1+x_2)/dt_1 + dx_1/dt_1 < 0$.

$$t_1=(x_1+x_2)\,(dy/dt_1)/(dx_1/dt_1).$$

According to (10), the denominator in the optimal trade policy for country T is surely negative. Therefore, the optimal trade policy t_1 has the opposite sign as that of dy/dt_1. By the result in Proposition 4, we thus have the following proposition regarding the source country's optimal trade policy.

Proposition 5: If and only if $\sigma_{12}>\sigma_2^2$, then the source country should use an export tax to raise its national welfare.

In contrast to the existing literature, our result that an export tax is welfare improving in the Cournot-quantity game is striking. For instance, Brander and Spencer (1985) obtain that an export subsidy is welfare improving when firms compete in the quantity. Our model considers a multinational firm with two plants located in different countries. With some uncertainty in the model, we are able to show that an export tax is called for to raise national welfare. According to Proposition 2, the export tax reduces the MNE's home production. However, the export tax encourages the MNE to trade off its overseas production expansion for the home production. Therefore, without this possibility of a trade-off between home and overseas production, it never pays for the source country to tax its home production.

With this possibility of a trade-off under uncertainty, we also need to ensure that the increase in the overseas production can outweigh the production deduction at home. That is why $\sigma_{12}>\sigma_2^2$ is required. Under the condition that $\sigma_{12}>\sigma_2^2$ holds, the export tax increases the MNE's overall production. As a result, the rival's output y falls and the source country's welfare increases. In a special case in which the equality $\sigma_{12}=\sigma_2^2$ holds, our model with different incentives for the MNE comes to the same laisser-faire trade policy as that in Ishii (2001).

The condition $\sigma_{12}>\sigma_2^2$ is equivalent to the one with $\sigma_2/\sigma_1<\rho$. Therefore, given a constant correlation coefficient ρ, an export tax with a relatively small variance of shock in the host country (σ_2^2) will reduce the MNE's home production, but will increase the MNE's global output. Notice that when shocks are stochastically, negatively correlated or not correlated at all, $\sigma_{12}\leq 0<\sigma_2^2$, the source country's export tax will surely reduce the MNE's total output and increase firm 2's output. In this case, a subsidy on the source country's production is optimal.

3.2 The host country's optimal policy

We now assume that country M's welfare is the sum of firm 2's profits plus tax revenues from the exports of firm 2 and MNE's subsidiary. We have

$$W^2 = \pi^2 + t_2(x_2 + y).$$

The first-order condition for country M's welfare maximization is, using (5),

$$\begin{aligned} dW^2/dt_2 &= (\partial\pi^2/\partial x_1)\,(dx_1/dt_2) + (\partial\pi^2/\partial x_2)\,(dx_2/dt_2) + (\partial\pi^2/\partial y)\,(dy/dt_2) \\ &\quad + \partial\pi^2/\partial t_2 + x_2 + y + t_2 d(x_2 + y)/dt_2 \\ &= -y[d(x_1 + x_2)/dt_2] + x_2 + t_2[d(x_2 + y)/dt_2]. \end{aligned} \tag{14}$$

The first two terms of the first equation in (14) represent the strategic effect of the host country's tax. In view of (14), this strategic effect depends on how the MNE's total output is affected by the tax rate. We assume that the second-order condition holds. Therefore, the social welfare function is strictly concave in the export tax rate t_2. Equating (14) to zero, we obtain the optimal trade policy for the host country:

$$t_2 = [yd(x_1 + x_2)/dt_2 - x_2]/[d(x_2 + y)/dt_2]. \tag{15}$$

According to (10), if and only if the host country's shock is less volatile than that in the home country, i.e., $\sigma_2 < \sigma_1$, then the host country's export tax will decrease the MNE's overall production. In this case, the numerator in (15) is surely negative. In Appendix D we prove that the denominator in (15) is always negative. We then obtain the following proposition regarding the host country's optimal trade policy.

Proposition 6: When the host country's shock is less volatile than that in the home country, i.e., $\sigma_2 < \sigma_1$, then an export tax is called for to raise the host country's welfare.

Notice that the host country's export tax applies to exports of both indigenous firm 2 and the MNE's subsidiary. According to Proposition 4 and under the condition $\sigma_2 < \sigma_1$, the tax does not necessarily increase firm 2's output. However, it is the tax effect on the MNE's global production that shifts profits from the MNE to firm 2. When the condition $\sigma_2 < \sigma_1$ holds, the host country's export tax also provides tax revenues for the host country. Therefore, in this case an export tax is optimal for the host country.

When $\sigma_2 > \sigma_1$, a tax increases the MNE's total output and firm 2 loses profits. Therefore, it provides an incentive for the host country to subsidize its exports. However, an export tax can still generate tax revenues for the host country. According to (15), the host country's optimal policy in this case depends on the relative market shares of the MNE's subsidiary production and firm 2's output. In particular, if and only if the MNE's subsidiary has a relatively high market share such that the condition $x_2/y > (2R/\Delta)(\sigma_2^2 - \sigma_1^2)$ holds, then firm 2's profit loss can be outweighed by the tax revenues collected. Consequently, a tax on all kind of exports is optimal for the host country.

4. Conclusions

We build a three-country model to study a strategic trade policy under uncertainty. A risk-averse MNE globally diversifies its production when taking into account local wages and tax advantages and to avoid risk in the world. In the model the governments of the source and host countries use an export policy to pursue their national welfare.

We prove that depending on random shocks' covariance in the world, the MNE's global production may move in the same or opposite direction in the equilibrium. Even if the source and the host countries have the same wage and tax structure, we demonstrate that as long as the ratio of variance of shocks is within an interval, the MNE will diversify its production in the two countries. We then show that the source country's export tax decreases the MNE's home production, but it might possibly increase its overseas production and the MNE's total output.

When the random shocks are stochastically, positively correlated, the host country's export tax will increase the MNE's home production. If not, then the export tax's effect on the MNE's decision may have any sign. However, we prove that if and only if the host country's random shock is more volatile than that in the home country, then the host country's export tax will surely increase the MNE's overall production.

We finally obtain that if and only if $\sigma_{12} > \sigma_2^2$, then the source country should use an export tax to raise its national welfare. On the other hand, when the host country's random shock is less volatile than that in the home country, i.e., $\sigma_2 < \sigma_1$, then an export tax is called for to raise the host country's welfare. If this does not occur, then when deciding the host country's optimal policy, one must consider the relative market shares of the indigenous firm and MNE's subsidiary.

Appendix

A. We prove that if the inequality condition $R\sigma_1\sigma_2(1-\rho)>4$ holds, then the second-order condition of the MNE's profit maximization is satisfied. We expand the second-order condition of the MNE's profit maximization and obtain

$$\begin{aligned}\Omega&=4+2R\sigma_2^2+2R\sigma_1^2+R^2\sigma_1^2\sigma_2^2-(4+4R\sigma_{12}+R^2\sigma_{12}^2)\\&=2R(\sigma_1+\sigma_2)^2+R\sigma_1\sigma_2(1+\rho)\,[R\sigma_1\sigma_2(1-\rho)-4].\end{aligned}$$

A sufficient condition to assure the second-order condition of the MNE's profit maximization is that the inequality $R\sigma_1\sigma_2(1-\rho)>4$ holds.

B. We derive the condition needed to assure that in an absolute sense the slope of the *ll* curve is greater than that of the *kk* curve in Figures 2 and 3. First of all, in an absolute sense the slope of the *ll* curve is greater than that of the *kk* curve if and only if

$$(3+2R\sigma_1^2)\,(3+2R\sigma_2^2)>(3+2R\sigma_{12})^2. \tag{B1}$$

Notice that the inequality in (B1) can be rearranged into

$$\begin{aligned}&\Omega+(1+R\sigma_1^2)\,(1+R\sigma_2^2)+(1+R\sigma_1^2)\,(2+R\sigma_2^2)+(1+R\sigma_2^2)\,(2+R\sigma_1^2)\\&\quad-2(2+R\sigma_{12})\,(1+R\sigma_{12})-(1+R\sigma_{12})^2.\end{aligned} \tag{B2}$$

Except for the first term, the remaining terms in (B2) can be further collected into

$$3R^2\sigma_1^2\sigma_2^2(1-\rho^2)+4R(\sigma_1-\sigma_2)^2+8R\sigma_1\sigma_2(1-\rho), \tag{B3}$$

which is positive without any condition. Therefore, the second-order condition of the MNE's maximization of $Eu(\pi^i)$, i.e., $\Omega>0$, is sufficient to assure that the slope of the *ll* curve is greater in an absolute sense than that of the *kk* curve in Figures 2 and 3.

C. We derive the market equilibrium for the MNE's output in the market. Rearranging equations (6) and (7) into a matrix form, we have

$$\begin{bmatrix}(3+2R\sigma_1^2) & (3+2R\sigma_{12})\\(3+2R\sigma_{12}) & (3+2R\sigma_2^2)\end{bmatrix}\begin{bmatrix}x_1\\x_2\end{bmatrix}=\begin{bmatrix}A-2(w_1+t_1)+(w_2+t_2)\\A-(w_2+t_2)\end{bmatrix}, \tag{C1}$$

where the variable Δ is defined as $\Delta \equiv (3+2R\sigma_1^2)(3+2R\sigma_2^2)-(3+2R\sigma_{12})^2$, which is positive as shown in Appendix B. The equilibrium home and overseas production outputs can be obtained by solving (C1). We have

$$
\begin{aligned}
x_1 &= (1/\Delta)\{(3+2R\sigma_2^2)[A-2(w_1+t_1)+(w_2+t_2)] \\
&\quad -(3+2R\sigma_{12})[A-(w_2+t_2)]\} \\
&= (1/\Delta)\{2R(\sigma_2^2-\sigma_{12})A-2(3+2R\sigma_2^2)(w_1+t_1) \\
&\quad +2[3+R(\sigma_2^2+\sigma_{12})](w_2+t_2)\}, \\
x_2 &= (1/\Delta)\{(3+2R\sigma_1^2)[A-(w_2+t_2)] \\
&\quad -(3+2R\sigma_{12})[A-2(w_1+t_1)+(w_2+t_2)]\} \\
&= (1/\Delta)\{2R(\sigma_1^2-\sigma_{12})A-2[3+R(\sigma_1^2+\sigma_{12})](w_2+t_2) \\
&\quad +2(3+2R\sigma_{12})(w_1+t_1)\}.
\end{aligned}
$$

D. By (10) and (12), the denominator in (15) is

$$
\begin{aligned}
dx_2/dt_2+dy/dt_2 &= -[6+2R(\sigma_1^2+\sigma_{12})]/\Delta - R(\sigma_2^2-\sigma_1^2)/\Delta - 1/2 \\
&= [2(-6-2R\sigma_1^2-2R\sigma_{12}-R\sigma_2^2+R\sigma_1^2)-\Delta]/2\Delta \\
&= (-12-2R\sigma_1^2-4R\sigma_{12}-2R\sigma_2^2-\Delta)/2\Delta.
\end{aligned}
$$

Therefore, when $\sigma_{12}>0$, the denominator in (15) is surely negative. On the other hand, if $\sigma_{12}<0$, then using $\Delta \equiv (3+2R\sigma_1^2)(3+2R\sigma_2^2)-(3+2R\sigma_{12})^2>0$, from which we can further rearrange the denominator into

$$dx_2/dt_2+dy/dt_2 = [-12-8R\sigma_1^2-8R\sigma_2^2+8R\sigma_{12}-4R^2\sigma_1^2\sigma_2^2(1-\rho^2)]/2\Delta<0.$$

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趨避風險之跨國籍企業與策略性貿易政策

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摘　要

我們在具不確定性下的三國模型中研究策略性貿易政策。趨避風險的跨國企業以水平式的外人投資方式取得世界各國工資與稅率的優勢，並降低其利潤風險。我們證明跨國企業在各地的生產量取決於隨機因子的共變異性而可能同向或反向相關。我們也證明當兩生產國隨機因子的變異性相對程度落在某區間時，跨國企業會把其產品分散在各地生產。我們進一步得證，如果受資國的市場變異性高於出資國的市場變異性，則受資國的出口稅會提升跨國企業全球產量。如果受資國的市場變異性低於兩生產國隨機因子的共變異性，出資國的出口稅會提升其社會福利；而如果受資國的市場變異性低於出資國的市場變異性，則受資國的最適貿易政策爲出口稅。

關鍵詞：趨避風險者，跨國籍企業，水平式外人投資，策略性貿易政策