行政院國家科學委員會專題研究計畫　成果報告

在需求不確定情況下的環境規範與廠商的最適區位

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行政院國家科學委員會專題研究計畫成果報告

在需求不確定情況下的環保規範與廠商的最適區位

Environment Regulation and The Firm's Optimal Location under Demand Uncertainty

計畫編號：**NSC 92-2415-H-032-008-**
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一、中文摘要

本計劃發展一個 Weberian 區位三角形的模型，探討在面對需求及環保政策不確定情況下，環保規範（即投資新技術以消除環保污染）對廠商最適區位抉擇的影響效果。本計劃的主要貢獻是求出環保規範標準的一些比較靜態分析結果。這些結果顯示環保規範標準是否隨空間距離而調整是評估該政策影響廠商區位的重要因素。

Abstract

This paper develops a Weberian locational triangle model to examine the impacts of environmental regulations on a firm's optimal location decisions under demand uncertainty. It provides a systematic analysis of a risk-averse firm's choice of plant location and its response to the costs of environmental regulation under uncertainty. This paper makes contributions to the literature by deriving comparative statics results with respect to the level of environmental regulation.

These results demonstrate that whether or not the regulation varies across space is an important factor for evaluating the possibility of individual firms relocationg in response to the costs of environmental regulation under uncertainty.

Key Words: Environmental Regulation, Optimal Demand Uncertainty, Environmental Policy Uncertainty Location

二、緣由與目的

This paper develops a Weberian locational triangle model to examine the impacts of environmental regulations on a firm's optimal location decisions under uncertainty about product demand. It provides a systematic analysis of a risk-averse firm's choice of plant location and its response to the costs of environmental regulation under uncertainty. This paper makes contributions to the literature by deriving comparative statics results with respect to the level of environmental regulation.

These results demonstrate that whether or not the regulation varies across space is an important factor for evaluating the possibility of individual firms relocationg in response to the costs of environmental regulation under uncertainty。

三、結果與討論

we consider a competitive firm employs two transportable inputs M_1 and M_2 which are available only at points A and B, respectively. These inputs are used to produce output q which is sold at a market (or consumption) center C as depicted in Figure 1, where E is the optimal location of the firm, s_1 and s_2 are distances of E from A and B, respectively, h is the distance between E and C, θ is the angle between CE and CA, β is the angle between CA and CB, and a and b are lengths of CA and CB, respectively.

The production function of the firm can be specified as:

$$q = f(M_1, M_2) \quad (1)$$

The production function implies a minimum cost function $C(w_1 + r_1 s_1, w_2 + r_2 s_2, q)$, where $(w_1 + r_1 s_1)$ and $(w_1 + r_2 s_2)$ are delivered price of inputs M_1 and M_2 respectively, and s_1 and s_2 are defined by the law of consines as $s_1 = \sqrt{a^2 + h^2 - 2ah\cos\theta}$ and $s_2 = \sqrt{b^2 + h^2 - 2bh\cos(\beta - \theta)}$ Assume the production function is homothetic, then we can write the total cost function as the product of two functions: a function of factor prices and another function of output Q only.[2] Thus we have:

$$C(q) = c(w_1 + r_1 s_1, w_2 + r_2 s_2)H(q) \quad (2)$$

where c is a function of the delivered prices of M_1 and M_2. As such, the average cost and marginal cost are derivable as

$$AC = \frac{C(q)}{q} = \frac{cH}{q} \quad (3)$$

$$MC = C'(q) = cH' \quad (4)$$

From (3) and (4), we can define the following relation:

$\frac{H}{q} > (=,<) H'$ if and only if the production function exhibits increasing(constant, decrea -sing) returns to scale.

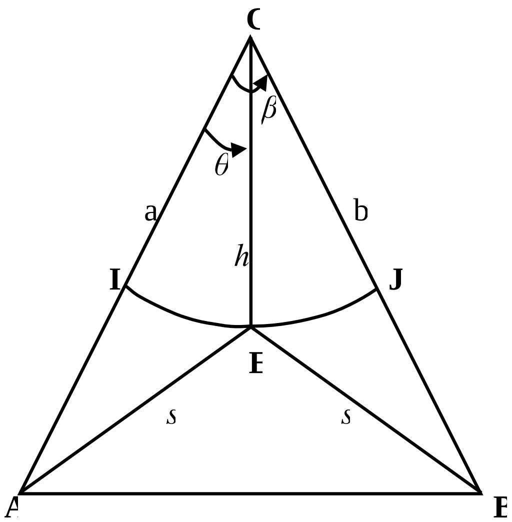

Figure 1 Locational Triangle

We consider mandatory technology adoption as the form of environmental regulation. In the presence of the environmental regulation, firms are usually required to use less pollution technologies, which require capital investment in new technologies. Assume that the fixed cost of abatement investment from the investment in a new technology depends upon where the firm locates its factory. Furthermore, it is assumed that the annualized fixed cost of abatement investment takes the following form: [3]

$$K(h) = \alpha k(h) \qquad (6)$$

where α is unit investment cost.

Given the above spatial setting of the firm, the profits of the firm are

$$\pi = (P - th)q - c(w_1 + r_1 s_1, w_2 + r_2 s_2) \cdot H(q) - \alpha k(h) \qquad (7)$$

where P is the price the firm receives for its product at the market center.

At what follows, we consider demand (or price) uncertainty that the firm faces in choosing its plant locations: demand (or price) and environmental policy uncertainty.

Ⅲ . Optimal Location under Demand Uncertainty

Assume that P is unknown at the time decisions have to be made. For simplicity, demand is assumed to be subject to additive demand uncertainty and given by:

$$P = \overline{P} + \gamma_1 \varepsilon_1 \qquad (8)$$

where ε_1 is a random variable such that $E(\varepsilon) = 0$, $E(\varepsilon^2) = 1$, $\overline{P} = E(P)$, γ_1 is a positive scaling parameters.

The firm has a subjective probability

density function regarding its profits which are given by:

$$\pi = [\overline{P} + \gamma_1 \varepsilon_1 - th]q - c(w_1 + r_1 s_1, w_2 + r_2 s_2) \cdot H(q) - \alpha k(h) \quad (9)$$

The production-location problem of the firm under demand uncertainty is to choose the optimal values of q, θ and h simultaneously so as to maximize its expected utility of the profits. That is,

M a x

$$G \equiv E[U(\pi_1)] = E[U\{[P + \gamma_1 \varepsilon_1 - TH]Q -$$

$$c(w_1 + \gamma_1 \varepsilon_1, w_2 + \gamma_2 s_2) H(q) - \alpha k(h)\}] \quad (10)$$

where $U(\pi_1)$ is a von Neumann-Morgenstern utility function such that $U' > 0$ and $U'' < 0$ (implying risk aversion).

The first-order conditions for the expected utility maximization are:

$$G_q = E[U'(\cdot)\{\overline{P} + \gamma_1 \varepsilon_1 - th - cH'(q)\}] = 0 \quad (11)$$

$$G_\theta = E[U'(\cdot)\{-c_\theta(\cdot) H(q)\}] = 0 \quad 12)$$

$$G_h = E[U'(\cdot)\{-tq - c_h(\cdot) H(q) - \alpha k'(h)\}] = 0 (13)$$

Moreover, the second-order conditions are assumed to be satisfied. Although vertex optima in the triangular space are quite possible, the implicit assumption that the optimal location cannot be at a vertex is reasonable for the qualitative analysis to be done. (See e.g., Miller and Jensen (1978), and Eswaran *et al* (1981)).

First of all, let us examine the impact of an increase in the cost of the environmental regulation on the optimum location of the firm by applying Cramer's rule to (14):

$$\frac{dh}{d\alpha} = \frac{G_{\theta\theta}}{D_1} [G_{q\alpha} G_{hq} - G_{h\alpha} G_{qq}] \quad (15)$$

where D_1 (the Hessian determinant associated with the system of (12)-(14)) < 0, $G_{\theta\theta} < 0$ and $G_{qq} < 0$ by the second-order conditions. Note that $G_{h\alpha} > 0$ and $G_{q\alpha} < 0$ if absolute risk aversion is decreasing (as shown in Katz (1984)), it follows from (15) that the sign of $\frac{dh}{d\alpha}$ depends on the sign of G_{hq}, which in turn is dependent upon not only the characteristics of the production function, but also the sign of $k'(h)$. Consequently, we can establish:

Proposition 1: *Under demand uncertainty and decreasing absolute risk aversion, an increase in the cost of the environmental regulation will move a risk-averse firm away from the output market if the regulation costs vary across space with* $k'(h) < 0$ *and if the production function is increasing or constant returns scale. Nevertheless, when the regulation is uniform across space with* $k'(h) = 0$ *, the optimum location will remain unchanged if the production function is constant returns to scale, but will move away from (closer to) the output market if the production function exhibits increasing (decreasing) returns to scale.*

Next, we consider the effect of an increase in the mean product price, $\overline{P}$, on the location of the firm. Via (14), we obtain:

$$\frac{dh}{d\overline{P}} = \frac{G_{\theta\theta}}{D_1}(G_{q\overline{P}}G_{hq}) \qquad (16)$$

Noting that $G_{q\overline{P}} > 0$ if absolute risk aversion is decreasing, it then intermediately follows from (16) that $\frac{dh}{d\overline{P}} \gtrless 0$ as $G_{hq} \gtrless 0$. Thus, we have:

Proposition 2: *Under demand uncertainty and decreasing absolute risk aversion, an increase in the mean product price will bring a risk-averse firm nearer to the market if* $k'(h) < 0$ *and the production function is increasing or constant returns to scale. Its impact is found to be ambiguous if the production function is decreasing returns to scale. When* $k'(h) = 0$ *(i.e., the regulation cost is uniform across space), the optimum location is invariant with respect to a change in the expected product price if the production function is constant returns to scale. However, it moves toward (away from) the market if production function exhibits increasing (decreasing) returns to scale.*

We now turn to the effect of a marginal increase in price uncertainty on the optimum location of the firm. From(14), we derive

$$\frac{\partial h}{\partial \gamma_1} = \frac{G_{\theta\theta}}{D_1}(G_{qr}G_{hg}) \qquad (17)$$

Noting that $G_{g\gamma} < 0$ if absolute risk aversion is decreasing. Hence, it follows from (17) that $\frac{\partial h}{\partial \gamma_1} \gtrless 0$ as $G_{qr} \gtrless 0$. Therefore, we have

Proposition 3: *Under demand uncertainty and* *decreasing absolute risk aversion, a mean-preserving increase in price uncertainty more the firm away form the market if* $k'(h) < 0$ *and the production function is increasing or constant returns to scale. But its impact on the optimum location is ambiguous if the production function is decreasing returns to scale. Nevertheless, if* $k^{'}(h) = 0$*, the optimum location move away from(nearer to) the market if the production is increasing (decreasing) returns to scale. The optimum (loctation remains unchanged if the production function is constant returns to scale.*

IV Concluding Remarks

This paper develops a Weberian locational triangle model to examine the impacts of environmental regulations on a firm's optimal location decisions under uncertainty about product demand. It provides a systematic analysis of a risk-averse firm's choice of plant location and its response to the costs of environmental regulation under uncertainty. This paper makes contributions to the literature by deriving comparative statics results with respect to the level of environmental regulation.

These results demonstrate that whether or not the regulation varies across space is an important factor for evaluating the possibility of individual firms relocationg in response to the costs of environmental regulation under uncertainty. More specifically, we obtain several striking results.

(i) We find that under demand uncertainty and decreasing absolute risk aversion, the impacts of an increase in the mean price as well as a mean-preserving increase in price uncertainty on the optimal locaton of the firm are ambiguous if the production function is decreasing returns to scale and if the cost of regulation decreases with increase in distance from the market. This is in constrast with Katz's(1984) result that the firm's optimal location moves away from (toward) the market as a result of an increase in the mean product price (a mean-preserving increase in price uncertainty) if the production function exhibits decreasing returns to scale. It should be emphasited that when the regulation costs are uniform across space $k^{'}(h) = 0$, these impacts is qualitatively similar to the one derived by Katz(1984).

(ii) Under demand uncertainty and decreasing absolute ridk aversion, an increase in the cost of environmental regulation(i.e., a stricter environmental policy) will move a risk-averse firm away from the output market if the regulation costs decrease with increase in distance from the market and if the production function is increasing or constant returns to scale. Nevertheless the impact is ambiguous if the production function is decreasing returns to scale. However, when the regulation is uniform across space, the optimum location will remain unchanged under constant returns production function, but will move away from(closer to) the output market if the production function is increasing(decreasing) returns to scale.

四、計劃成果自評

The comparative statics results derived in this paper have implications for the design and implementation of environmental policies for controlling pollution. In addition, these results have implications for difference in U.S. state water quality regulations and their influence on the locations of firms in the U.S. It also provides a reasonable explanation for the possibility of the U.S. manufacturing plant relocating to Mexico which was an important issue in North American Free Trade Agreement debate.

Our study not only contribute to the literature, but also provides some policy implications for decision-makers. We wish to publish our work in international journal.

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