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Government Subsidy Mechanisms for Addressing Supplier Noncompliance in Emission Reduction

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Abstract. This study models a sequential game among a government, a focal firm, and a supplier that may underinvest in compliant emission reduction. It compares a direct subsidy to the supplier with an indirect subsidy to the focal firm for supplier support. Direct subsidies correct supplier underinvestment; focal firms also support suppliers when demand is positive, but choose less support than is socially optimal. The choice of subsidy recipient depends on the focal firm's support cost. When the support cost is low, the indirect subsidy dominates in both compliance level and social welfare. When the support cost is high, the direct subsidy dominates in both dimensions. At an intermediate support cost, the direct subsidy generates a higher compliance level, whereas the indirect subsidy yields greater social welfare. Therefore, the government should select the subsidy recipient according to its policy objective and the focal firm's actual support efficiency.

Keywords: low-carbon supply chain, emission-reduction noncompliance, government subsidy, focal-firm support, game theory

1. Introduction

Upstream suppliers account for much of supply-chain emissions but often lack finance, technology, and carbon-management capability, which can induce concealment or data falsification. Cases involving Lehigh Southwest Cement, Beijing Hyundai Mobis, and Hino Motors show that supplier noncompliance can trigger regulatory action, shipment disruption, and market losses [1-3]. Focal firms can mitigate these risks by transferring technology, data, and organizational capabilities. Shanghai's low-carbon supply-chain policy and Apple's supplier clean-energy program illustrate this approach [4, 5].

Research on supplier noncompliance emphasizes audits and disclosure. Joint audit strategies affect incentives and environmental performance [2], while disclosure is effective only when suppliers possess sufficient compliance capability [6]. These studies say less about capability-building that directly lowers compliance costs. A second literature examines subsidies and low-carbon coordination, including corporate social responsibility, blockchain-enabled subsidies, collaborative innovation, asymmetric information [7-10]. It usually subsidizes emission-reducing firms, output, or innovation. Directly subsidizing a supplier and subsidizing a focal firm to support that supplier have rarely been compared within one framework, especially when compliance and welfare objectives diverge.

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Accordingly, this study asks how the two mechanisms affect compliance, how focal-firm support cost determines the preferred recipient, and whether compliance maximization and welfare maximization imply different policies. The study contributes by (i) integrating supplier noncompliance, focal-firm support, and two subsidy channels in one game; (ii) showing why privately chosen support is below the social optimum; and (iii) deriving distinct compliance and welfare thresholds that create an objective conflict at intermediate support costs.

2. Problem description and basic assumptions

2.1. Problem description

Consider a supply chain composed of a government agency G, a focal firm B, and a supplier S. The supplier is responsible for production and emission reduction, while the focal firm purchases the product and sells it to the end market. Because compliant emission reduction is costly, the supplier may falsely claim that it has met the required standard. The focal firm, whose demand, reputation, and supply chain governance responsibilities are affected by such behavior, may use technological, data-related, and organizational empowerment to improve the supplier's compliance capabilities.

The government may subsidize either the supplier's compliance effort or the focal firm's support cost. Table 1 separates these effects into four modes.

Table 1. Four decision modes

Mode	Focal-firm support	Government subsidy recipient	—	—	—
A	No	None	C	Yes	None
B	No	Supplier	D	Yes	Focal firm

2.2. Basic assumptions

(1) Supply chain structure and pricing. The supplier produces at a unit cost c. The focal firm purchases at an exogenous wholesale price w and sells at a retail price p, where $p > w > c > 0$.

(2) Compliance level and market demand. The supplier's compliance level is $e \in [0,1]$, and $1-e$ represents the proportion of falsely reported emission reduction. Let $\lambda > 0$ denote the market's sensitivity to fraudulent emission-reduction claims. Demand is given by $D = 1 - p - \lambda(1-e)$.

(3) Self-directed emission reduction and support technology. Without support, the supplier's self-directed emission-reduction cost is $C_S(e) = ke^2/2$.

After the focal firm provides an effective support level h ($0 \le h \le e$), the supplier's residual emission-reduction cost and the focal firm's support cost are, respectively, $C_S(e,h) = k(e-h)^2/2, C_B(h) = gh^2/2$,

where $k > 0$ and $g > 0$ are the cost coefficients of self-directed emission reduction and focal-firm support, respectively.

(4) Subsidies and social welfare. Under the direct subsidy, the government bears a proportion $\alpha \in (0,1)$ of the supplier's emission-reduction cost. Under the indirect subsidy, the government bears a proportion $\beta \in (0,1)$ of the focal firm's support cost. Consumer surplus and environmental damage are, respectively, $CS = D^2/2, E = \delta(1-e)$,

where $\delta > 0$ denotes the environmental damage caused by one unit of noncompliant emission reduction. Social welfare equals total firm profits plus consumer surplus, less subsidy expenditure and environmental damage.

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(5) Game sequence. In Modes A and B, the government first determines the subsidy policy, the supplier then chooses e, and the focal firm finally chooses p. In Modes C and D, the government first determines the subsidy policy, the focal firm then chooses h, the supplier chooses e, and the focal firm finally chooses p. The government chooses the subsidy rate to maximize social welfare, while firms maximize their own profits.

3. Model and equilibrium results

3.1. Profits and social welfare

Given the compliance level, the pricing and demand responses are identical across the four modes:

$$p(e) = (1 - \lambda + \lambda e + w)/2, \quad D(e) = (1 - \lambda - w + \lambda e)/2.$$

The profit functions under the four modes can be written compactly as

$A: \pi_B^A = (p - w)D, \pi_S^A = (w - c)D - ke^2/2;$

$B: \pi_B^B = (p - w)D, \pi_S^B = (w - c)D - (1 - \alpha)ke^2/2;$

$C: \pi_B^C = (p - w)D - gh^2/2, \pi_S^C = (w - c)D - k(e - h)^2/2;$

$D: \pi_B^D = (p - w)D - (1 - \beta)gh^2/2 \pi_S^D = (w - c)D - k(e - h)^2/2.$

Government subsidy expenditures in Modes B and D are, respectively, $S^B = \alpha ke^2/2, S^D = \beta gh^2/2$, while $S = 0$ in the other modes. Social welfare in all four modes is $SW = \pi_B + \pi_S + D^2/2 - S - \delta(1 - e)$.

3.2. Equilibrium results

For notational convenience, define

$$N = 4\delta + 3\lambda(1 - \lambda - w) + 2\lambda(w - c), \qquad M = 8k\delta + 6k\lambda(1 - \lambda - w) + 3\lambda^3(w - c),$$

$T = M + 4k\lambda(w - c).$

Lemma 1. Suppose that $k > 3\lambda^2/4$, $g > 3\lambda^2/4$, and all equilibrium decisions, subsidy rates, and market demand are feasible interior solutions. Then a unique equilibrium exists in each of the four modes.

Proposition 1. The unique interior equilibrium in Mode A is reported in Table 2.

Proposition 2. When $k > 3\lambda^2/4$, the unique interior equilibrium in Mode B is reported in Table 2.

Proposition 3. When $2g > \lambda^2$, the unique interior equilibrium in Mode C is reported in Table 2.

Proposition 4. When $g > 3\lambda^2/4$, the unique interior equilibrium in Mode D is reported in Table 2.

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Table 2. Core equilibrium outcomes under the four modes

Mode	Optimal subsidy rate	Support level	Compliance level
A	—	—	$e^A = \lambda\big(w-c\big)/\big(2k\big)$
B	$\alpha^{B^*} = \Big[2kN - \lambda\big(w-c\big)\big(4k-3\lambda^2\big)\Big]/\big(2kN\big)$	—	$e^B = N/\big(4k-3\lambda^2\big)$
C	—	$h^C = \lambda\big[2k\big(1-\lambda-w\big)+\lambda^2\big(w-c\big)\big]/\big[2k\big(2g-\lambda^2\big)\big]$	$e^C = e^A + h^C$
D	$\beta^{D^*} = \dfrac{(2g-\lambda^2)T - \lambda\big[2k\big(1-\lambda-w\big)+\lambda^2\big(w-c\big)\big]\big(4g-3\lambda^2\big)}{2gT}$	$h^D = \dfrac{T}{2k(4g-3\lambda^2)}$	$e^D = e^A + h^D$

Backward induction yields the equilibria in Table 2; under Lemma 1, every stage is strictly concave.

For any mode $i \in \{A, B, C, D\}$, equilibrium demand and price are given by $D^i = \big(1-\lambda-w+\lambda e^i\big)/2, p^i = w + D^i$. The focal firm's equilibrium profit is

$$\pi_B^A = \big(D^A\big)^2, \quad \pi_B^B = \big(D^B\big)^2, \qquad \pi_B^C = (D^C)^2 - g(h^C)^2/2,$$

$$\pi_B^D = (D^D)^2 - (1-\beta^{D*})g(h^D)^2/2.$$

The supplier's equilibrium profit is

$$\pi_S^A = (w-c)D^A - k(e^A)^2/2, \pi_S^B = (w-c)D^B - (1-\alpha^{B*})k(e^B)^2/2,$$

$\pi_S^i = (w-c)D^i - k(e^i-h^i)^2/2, \quad i \in \{C, D\}.$

After netting out subsidy transfers, social welfare can be written uniformly in terms of real resource costs as $SW^i = 1.5\big(D^i\big)^2 + \big(w-c\big)D^i - k\big(e^i\big)^2/2 - \delta\big(1-e^i\big), \quad i \in \big\{A, B\big\},$

And $SW^i = 1.5(D^i)^2 + (w-c)D^i - k(e^i-h^i)^2/2 - g(h^i)^2/2 - \delta(1-e^i),$

$i \in \{C, D\}.$

Corollary 1: Basic incentive effects. Within the interior parameter region specified in Lemma 1, and provided that $D^A > 0, e^B > e^A, h^C > 0, e^C = e^A + h^C > e^A$, and $h^D > h^C, e^D > e^C$.

The direct subsidy corrects the supplier's underinvestment in compliance. Demand expansion gives the focal firm an endogenous incentive to support the $D^A > 0$ supplier. Because the focal firm does not internalize all social benefits, the indirect subsidy can correct insufficient private support.

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Demand, supply chain member profits, and social welfare also improve accordingly under the corresponding modes.

4. Subsidy-recipient selection and the dual-threshold structure

4.1. Comparison of compliance performance

Proposition 5: Comparison of compliance performance under the two subsidy mechanisms. Define $g_e^* = 2k^2N/M$. Then $e^D > e^B \Leftrightarrow g < g_e^*$, and $e^D < e^B \Leftrightarrow g > g_e^*$. The sign-determining difference is

$$e^D - e^B = 2M\left(g_e^* - g\right) / \left[k\left(4g - 3\lambda^2\right)\left(4k - 3\lambda^2\right)\right].$$

Within the parameter region specified in Lemma 1, the denominator and M are positive. Therefore, the sign of the difference depends only on $g_e^* - g$. Indirect subsidies yield higher compliance below the threshold; direct subsidies do so above it.

4.2. Comparison of social welfare

Proposition 6: Comparison of social welfare under the two subsidy mechanisms. Define $g_{SW}^* = 3\lambda^2/4 + \left(4k - 3\lambda^2\right)T^2/\left(4M^2\right)$. Then $SW^D > SW^B \Leftrightarrow g < g_{SW}^*$, and $SW^D < SW^B \Leftrightarrow g > g_{SW}^*$. The sign-determining difference is $SW^D - SW^B = M^2\left(g_{SW}^* - g\right) / \left[8k^2\left(4g - 3\lambda^2\right)\left(4k - 3\lambda^2\right)\right]$.

Within the parameter region specified in Lemma 1, the sign of the difference depends only on $g_{SW}^* - g$. Because welfare includes environmental damage, consumer surplus, profits, and real resource costs, higher compliance need not imply higher welfare.

4.3. Policy regions under the dual-threshold structure

Corollary 2: Dual-threshold structure for selecting the subsidy recipient. The two thresholds satisfy $g_e^* < g_{SW}^*$, with $g_{SW}^* - g_e^* = k\lambda(w-c)(4k-3\lambda^2)/M + [4k^2\lambda^2(w-c)^2(4k-3\lambda^2)]/M^2 > 0$.

Accordingly, the choice of subsidy recipient can be divided into three regions $g < g_e^* : e^D > e^B,\ SW^D > SW^B$, $g_e^* < g < g_{sw}^* : e^D < e^B,\ SW^D > SW^B$, $g > g_{sw}^* : e^D < e^B,\ SW^D < SW^B$.

(1) Low support-cost region. When $g < g_e^*$, the indirect subsidy dominates in both the compliance level and social welfare. When the focal firm already has mature supplier-collaboration systems and green capability-building foundations, the government should prioritize subsidizing the focal firm.

(2) Intermediate support-cost region. When $g_e^* < g < g_{SW}^*$, the direct subsidy produces a higher compliance level, while the indirect subsidy generates greater social welfare. Maximizing compliance and maximizing social welfare may therefore lead to different subsidy-recipient choices: the former objective supports a direct subsidy, whereas the latter supports an indirect subsidy.

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(3) High support-cost region. When $g > g_{SW}^{*}$, the direct subsidy dominates in both the compliance level and social welfare. In this region, developing compliance capabilities through focal-firm support requires relatively high real resource costs, so the government should directly subsidize the supplier.

At $g = g_{e}^{*}$ or $g = g_{SW}^{*}$, the associated outcomes are equal. Otherwise, recipient selection depends on support efficiency and the policy objective.

5. Conclusion

Direct subsidies lower the supplier's marginal compliance cost. Positive baseline demand also gives the focal firm an incentive to support the supplier, but private support remains below the social optimum, justifying an indirect subsidy.

The choice of subsidy recipient exhibits a dual-threshold structure satisfying $g_{e}^{*} < g_{SW}^{*}$. Indirect subsidies dominate both outcomes at low support cost; direct subsidies dominate at high cost. In the intermediate region, direct subsidies yield higher compliance but indirect subsidies higher welfare, so the objective determines the preferred recipient.

Policy should be based on measured support efficiency, including technology transfer, carbon-data capability, collaboration experience, and abatement improvement per unit of investment. In the intermediate region, governments must specify whether compliance or welfare is primary; compliance alone is not a sufficient welfare metric.

The model abstracts from endogenous wholesale prices, supplier heterogeneity, and crowding out; these extensions are left for future research.

References

[1] Fu, H. Y., Lei, Y. F., Zhang, S. G., et al. (2023). Tolerance vs. suppression: Research on carbon audit mechanism for supply chain's noncompliance with emission reduction standards. *Management Review, 35*(10), 298–309.

[2] Fu, H. Y., Lei, Y. F., Dan, B., et al. (2025). Carbon audit strategies for managing supplier emission-reduction noncompliance: Independent vs. joint. *Chinese Journal of Management Science, 33*(9), 339–348.

[3] Toyota Motor Corporation. (2022, August 22). Statement concerning additionally found wrongdoings by Hino Motors in application for engine emissions certification and suspension of shipments of Toyota Dyna trucks. *Toyota Motor Corporation*. https://global.toyota/en/newsroom/corporate/37890473.html

[4] General Office of the Shanghai Municipal People's Government. (2024, March 25). Notice on issuing the action plan of Shanghai for accelerating the establishment of a product carbon-footprint management system and building green and low-carbon supply chains. *Shanghai Municipal People's Government*. https://www.shanghai.gov.cn/nw12344/20240325/9ddcd99b89f14cb2a3c301ab8fc8c859.html

[5] Apple Inc. (2023, April 5). Apple and global suppliers expand renewable energy to 13.7 gigawatts. *Apple Newsroom*. https://www.apple.com/newsroom/2023/04/apple-and-global-suppliers-expand-renewable-energy-to-13-point-7-gigawatts/

[6] Chen, Q., & Duan, Y. (2023). Impact of information disclosure on global supply chain greenwashing: Is more information transparency always better? *Transportation Research Part E: Logistics and Transportation Review, 178*, 103288.

[7] Lin, Z. B., & Bao, L. (2021). Research on the effects of CSR on supply chain emission-reduction decision-making and government subsidy efficiency. *Chinese Journal of Management Science, 29*(11), 111–121.

[8] Zhang, L. R., Peng, B., & Cheng, C. Q. (2023). Research on government subsidy strategies for low-carbon supply chains based on blockchain technology. *Chinese Journal of Management Science, 31*(10), 49–60.

[9] Zhang, P., Jin, L., & Wang, Y. (2023). Optimizing mechanisms for promoting low-carbon manufacturing industries towards carbon neutrality. *Renewable and Sustainable Energy Reviews, 183*, 113516.

[10] He, L., Wang, H., & Liu, F. (2024). Emission abatement in low-carbon supply chains with government subsidy and information asymmetry. *International Journal of Production Research, 62*(18), 6598–6626.