Competitors as Whistleblowers in Enforcement of Product Standards

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LARGE MARKETS RESTRICT HAZARDOUS SUBSTANCES IN ELECTRONICS

EU, China, California “Restrictions on Hazardous Substances”: illegal to sell electronics containing lead, mercury, cadmium, brominated flame retardants

Testing for compliance is costly (e.g., for laptop is $200,000)

Dutch authorities, acting on tip-off from competitor about cadmium in a cable, halted sale of Sony Playstations; Sony lost $110 million in revenue.

Should regulator rely on manufacturers for testing?

What are the impacts of competitive testing on industry structure and performance?
REACH
COMPETITORS MORE EFFICIENT THAN REGULATOR IN DETECTING VIOLATIONS

Manufacturers have equipment and trained staff to test their own products, so can easily test competitor’s products.

Often purchase competitors’ products to evaluate other characteristics.

Understand through their own compliance efforts how a product is most likely to fail.

May have common base of suppliers.

Regulator revenue for testing raised through distortionary taxes.
Manufacturer 1 with quality $u_1$  

Manufacturer 2 with quality $u_2$  

Manufacturer $n$ with quality $u_n$ chooses...  
  - quantity $Q_n$  
  - compliance $e_n$  
  - testing $t_{nm}$  

Manufacturer $N$ with quality $u_N$  

Market: customer utility from product $i$ is  
$\nu u_i - p$  
where  
$\nu \sim \text{uniform}(0, \overline{\nu})$
MODEL – COURNOT OLIGOPOLY WITH COMPLIANCE AND TESTING DECISIONS

Manufacturer 1 with quality $u_1$

Manufacturer 2 with quality $u_2$

... Manufacturer $n$ with quality $u_n$ chooses...

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compliance $e_n$

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...Manufacturer $N$ with quality $u_N$
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Social Welfare

\[
\Sigma_{n=1}^{N} \left\{ E[v u_n \tilde{Q}_n (1 - \Sigma_{n=1}^{N} \tilde{Q}_n / 2) - x(1 - e_n)[1 - d(t_{R_n} + \Sigma_{m=1}^{N} t_{mn})]Q_n] - C(e_n) \right\}
\]

0 w.p. \( (1 - e_n) d(t_{R_n} + \Sigma_{m=1}^{N} t_{mn}) \)

\[
\tilde{Q}_n = \begin{cases} 
0 & \text{w.p. } (1 - e_n) d(t_{R_n} + \Sigma_{m=1}^{N} t_{mn}) \\
Q_n & \text{otherwise}
\end{cases}
\]

Manufacturer \( n \) chooses...

Manufacturer 1 with quality \( u_1 \)

Manufacturer 2 with quality \( u_2 \)

\[
t_{1n} \quad t_{2n} \quad \ldots \quad \ldots \quad t_{Nn}
\]

Manufacturer \( N \) with quality \( u_N \)

Manufacturer sells

\[
\tilde{Q}_n = \begin{cases} 
0 & \text{w.p. } (1 - e_n) d(t_{R_n} + \Sigma_{m=1}^{N} t_{mn}) \\
Q_n & \text{otherwise}
\end{cases}
\]

Social Welfare

utility units generate

social cost of noncompliance

compliance effort cost

testing cost

Manufacturer \( n \) sells

\[
\tilde{Q}_n = \begin{cases} 
0 & \text{w.p. } (1 - e_n) d(t_{R_n} + \Sigma_{m=1}^{N} t_{mn}) \\
Q_n & \text{otherwise}
\end{cases}
\]

at price

\[
p_n = \bar{v} \left( u_n - \Sigma_{i=1}^{N} \min(u_n, u_i) \tilde{Q}_i \right)
\]
Begin by focusing on setting where
• quantity/capacity fixed (short run equilibrium in compliance and testing)
• consumers are indifferent to product compliance

Results extend when both assumptions are relaxed:
• quantity endogenous
• consumers value compliance and form rational expectations regarding firms’ compliance and testing
REGULATOR TESTING CROWDS OUT TESTING BY COMPETITORS

If regulator accepts evidence of violations from competitors…

Under symmetric “quality” $u$:

- There is a unique symmetric equilibrium in compliance and testing by each manufacturer
- Low level of regulator testing has no effect on equilibrium compliance and total testing
- High level of regulator testing causes manufacturers not to test

Under asymmetric “quality” $u_n$:

- Low level of regulator testing $\rightarrow$ same set of equilibria in compliance, total testing, detection probability
- High level of regulator testing causes manufacturers not to test
Analytical Result:
Regulator maximizes expected social welfare by...

- not accepting evidence of violations from competitors
- testing at a high level that causes competitors not to test
- not testing; relying solely on competitive testing

social cost parameter $x$
COMPETITIVE TESTING INEFFECTIVE WITH LARGE NUMBER OF FIRMS

Analytical Result:
Under competitive testing, symmetric equilibrium compliance effort is decreasing in the number of firms $N$.

Intuition:
As number of firms increases...
- total equilibrium testing applied to each firm decreases because
  - value of knocking out a competitor is smaller
  - free rider problem in testing is exacerbated
COMPETITIVE TESTING INEFFECTIVE WITH LARGE NUMBER OF FIRMS

Analytical Result:
Under competitive testing, symmetric equilibrium compliance effort is decreasing in the number of firms $N$.

Intuition:
As number of firms increases…
• total equilibrium testing applied to each firm decreases
  ↓
  smaller chance of getting caught
  invest less in compliance

• market is more competitive, decreasing value of bringing goods to market

Competitive testing fails in “competitive industries” (many firms) and only succeeds in “uncompetitive industries” (few firms)
COMPETITIVE TESTING INEFFECTIVE WITH LOW QUALITY FIRMS

Analytical Result:
Under competitive testing, symmetric equilibrium compliance effort is decreasing in the “quality” level $u$

Intuition:
As a firm’s “quality” increases…
…its incentive for compliance increases (because firm has more to lose from being discovered as noncompliant)

…the incentive for its competitors to test the firm increases (because the competitors have more to gain by knocking out a high-quality firm)
COMPETITIVE TESTING ENCOURAGES ENTRY BY SMALL, LOW-QUALITY MANUFACTURERS

Analytical Result:
If manufacturer $n$’s “quality” $u_n$ or capacity $Q_n$ is sufficiently small, then in any Nash equilibrium, manufacturer $n$...

- draws less testing from its competitors
  \[ \sum_{i \neq n} t_{in} < \sum_{i \neq m} t_{im} \text{ for all } m \neq n \]
- does not comply with standard
  \[ e_n = 0 \]
- does not test its competitors’ products
  \[ t_{nm} = 0 \text{ for all } m \neq n \]
- has strictly greater expected profit

value of knocking out small, low-quality mfg. is small
market is less valuable to small, low-quality mfg.
EXTENSION TO ENDOGENOUS “QUALITY”: COMPETITIVE TESTING REDUCES “QUALITY”

Analytical Result:
Suppose that manufacturers choose “quality,” compliance and testing simultaneously. Then the product standard, enforced through competitive testing, reduces the equilibrium quality of the highest-quality product.

If “quality” were observed before testing, manufacturer would have even stronger incentive to reduce quality, in order to avert testing by competitors.
LONG-RUN PROBLEMS WITH ENFORCEMENT BY COMPETITIVE TESTING

- Product standard enforced through competitive testing
- Entry by low-“quality” manufacturers
- Less “quality” investment by incumbents
- Less competitive testing and compliance
SUMMARY

Relying on competitive testing to enforce a product standard will tend to be effective when...

- The industry is dominated by a small number of players (but enough to discourage collusion)
- Firms have strong brands to protect and “pricing power”; market in which the firms compete is attractive/profitable
- Firms are more efficient than regulator at detecting violations
- Barriers prevent entry by small firms with weak quality/brand

Relying on competitive testing may cause entry and reduced investment in brand/quality, and thus ultimately result in low compliance
APPENDIX
SUMMARY OF RESULTS

Relying on competitive testing to enforce regulations is effective in a range of circumstances…

Competitive testing fails in competitive industries (many firms) and only succeeds in uncompetitive industries.

Competitive testing creates incentive for entry by environmentally-damaging “white box” manufacturers.

Results apply more broadly to competitive markets governed by product-based health, safety standards.
EXTENSIONS AND DIRECTIONS FOR FUTURE RESEARCH

Possibility of collusion

RoHS violations reduce brand value in subsequent periods

Environmental nonprofits test products

Environmental costs depend on hazardous substance content and how disposed at end-of-life

\[
\text{reduced by private reporting, but relevant with few firms} \\
\text{reinforces conclusion that firms with stronger brands will have higher compliance}
\]
POLICY IMPLICATIONS

Relying on competitive testing to enforce regulations will tend to be effective when...

The industry is dominated by a small number of players (but enough to discourage collusion)

Firms have strong brands to protect and “pricing power”; market in which the firms compete is attractive/profitable

Firms are better informed about:
• the costs and means of compliance (environmental improvement)
• how to detect violations by other firms

Barriers prevent entry by small firms that could produce in an environmentally damaging way
APPENDIX
FIRMS MAY BENEFIT BY REGULATION

Numerical Result:
For some parameters

\[
\text{mfg. expected profit without RoHS} < \text{mfg. expected profit with RoHS and only competitive testing} < \text{mfg. expected profit with RoHS and regulator testing}
\]

Intuition:

**Negative Impact of RoHS/Testing on Mfg.**
- Possible blocking of mfg’s product
- Higher production cost

may be outweighed by

**Positive Impact of RoHS/Testing on Mfg.**
- Higher expected price
- Regulator testing saves mfg. cost of testing
FIRMS MAY BENEFIT BY REGULATION

Numerical Result:
For some parameters

\[
\begin{align*}
\text{mfg. expected profit} & \quad \text{mfg. expected profit} & \quad \text{mfg. expected profit} \\
\text{without RoHS} & \lesssim \text{with RoHS and only} & \lesssim \text{with RoHS and} \\
\text{competitive testing} & \quad \text{competitive testing} & \quad \text{regulator testing}
\end{align*}
\]

If, in addition, the environmental cost is moderate \( x \in (\underline{x}, \bar{x}) \),
then both firms and society are better off under competitive testing.
LONG-RUN EQUILIBRIUM: ENVIRONMENTAL COST DECREASING IN COST OF ENTRY

Extend Formulation to Longer Time Scale:
Firms make entry decisions
(enter i.f.f. expected profit exceeds entry cost $K$)
Firms make compliance, testing, and quantity decisions

Numerical Results: Impact of increasing entry cost

- Fewer firms enter
- Higher compliance $e_n$
- Lower total production $\sum_{n=1}^{N} Q_n$
- Lower total noncompliant production $\sum_{n=1}^{N} (1 - e_n)Q_n$
- Lower environmental cost $x \sum_{n=1}^{N} (1 - e_n)Q_n$
NUMBER OF ENTRANTS DECREASES IN ENTRY COST

- Number of firms with no regulation
- Number of firms under competitive testing

entry cost
COMPLIANCE INCREASES IN ENTRY COST

- Compliance under competitive testing
- Detection probability under competitive testing

(entry cost)
NONCOMPLIANT PRODUCTION DECREASES IN ENTRY COST

- total production = sales with no regulation
- total production under competitive testing
- total expected sales under competitive testing
- total expected noncompliant units under competitive testing

(entry cost)
INCENTIVES FOR COMPLIANCE AND TESTING

Manufacturer $n$’s profit:

$$\overline{v}[u_n(1-Q_n - \sum_{m=n+1}^{N} s_m Q_m) - \sum_{m=1}^{N-1} u_m s_m Q_m] s_n Q_n - c(e_n) Q_n - F(e_n) - \sum_{m \neq n} t_{nm}$$

Optimal compliance

- increases with testing of manufacturer $n$
- increases with “quality” of manufacturer $n$’s product
- decreases with competitor quantity
- decreases with competitors’ success probability

Optimal testing of competitor $m$

- increases with competitor’s quantity and “quality”
- decreases with competitor’s compliance
MODEL – COURNOT OLIGOPOLY WITH COMPLIANCE AND TESTING DECISIONS

Manufacturer 1 with quality $u_1$

Manufacturer 2 with quality $u_2$

Manufacturer $n$ with quality $u_n$ chooses...

Manufacturer $N$ with quality $u_N$
MODEL – COURNOT OLIGOPOLY WITH COMPLIANCE AND TESTING DECISIONS

Manufacturer 1 with quality $u_1$

Manufacturer 2 with quality $u_2$

Manufacturer $n$ with quality $u_n$ chooses... quantity $Q_n$, compliance $e_n$, testing $t_{nm}$

Manufacturer $N$ with quality $u_N$
Manufacturer 1 with quality $u_1$

Manufacturer 2 with quality $u_2$

Manufacturer $n$ with quality $u_n$ chooses...

- quantity $Q_n$
- compliance $e_n$
- testing $t_{nm}$

Manufacturer $N$ with quality $u_N$
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Manufacturer 1 with quality $u_1$

Manufacturer 2 with quality $u_2$

...

Manufacturer $n$ with quality $u_n$ chooses... quantity $Q_n$
compliance $e_n$
testing $t_{nm}$

...}

Manufacturer $N$ with quality $u_N$
MODEL (SHAKED & SUTTON ’82)

\(N\) manufacturers with “quality” \(u_1 \leq u_2 \leq \ldots \leq u_N\)

Customer utility \(\nu u_n - p_n\) where \(\nu \sim \text{uniform}[0, \bar{\nu}]\)

Manufacturer \(n\) chooses:

- production quantity \(Q_n\)
- compliance effort to eliminate hazardous substances \(e_n\)
- Testing of other manufacturer \(m\)’s products \(t_{nm}\)

\(\tilde{Q}_n = \begin{cases} 
0 & \text{w.p. } d\left( \sum_{j \neq n} t_{jn} \right)(1 - e_n) \\
Q_n & \text{w.p. } s_n \equiv 1 - d\left( \sum_{j \neq n} t_{jn} \right)(1 - e_n)
\end{cases}\)

and sells

at price \(p_n = \bar{\nu}(u_n - \sum_{m=1}^{N} \min[u_n, u_m] \tilde{Q}_m)\)
ASymmetRic information

Manufacturer knows compliance cost: \( c(e_n)Q_n + F(e_n) \)

Regulator only knows \( m(c(e_n)Q_n + F(e_n)) \) \( m \sim N(1, \sigma) \)

Manufacturer knows better than regulator how to test

Environmental impact is \( x \sum_{n=1}^{N} (1 - e_n)Q_n \)

Conjecture: The regulator should impose RoHS iff \( x \geq x \), and should test iff \( x \geq \bar{x} \) where \( 0 < x < \bar{x} \). Both thresholds increase with the regulator’s uncertainty about the cost of compliance and how to test.
COMPETITIVE TESTING INEFFECTIVE WITH LARGE NUMBER OF FIRMS OF LOW QUALITY

Analytical Result:
Under competitive testing, equilibrium compliance effort is decreasing in the number of firms $N$.

Intuition:
As number of firms increases…
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  - free rider problem in testing is exacerbated
- smaller chance of getting caught
- market is more competitive, decreasing value of bringing goods to market.
INCENTIVES FOR COMPLIANCE AND TESTING

Manufacturer $n$’s expected profit:

$$
\bar{v} \left[ u_n \left( 1 - Q_n - \sum_{m=n+1}^{N} s_m Q_m \right) - \sum_{m=1}^{n-1} u_m s_n Q_m s_n Q_n - c(e_n) Q_n - F(e_n) - \sum_{m \neq n} t_{nm} \right]
$$

Optimal compliance $e_n$

- increases with testing of manufacturer $n$ $\sum_{j \neq n} t_{jn}$
- increases with “quality” $u_n$
- decreases with competitor’s quantity $Q_m$ and success prob $s_m$

Optimal testing of competitor $m$ $t_{nm}$

- increases with competitor’s quantity $Q_m$ and “quality” $u_m$
- decreases with competitor’s compliance $e_m$
CONCLUSIONS

- Regulator may rely on manufacturers for testing.

- This creates incentive for entry by small, noncompliant “white box” manufacturers.

- To reduce entry, impose brand-registry fee:
  - used in Maine to fund collection & recycling of E-waste
  - increases RoHS-compliance,
  - reduces production
  - reduces environmental impact.
MODEL – COURNOT OLIGOPOLY WITH COMPLIANCE AND TESTING DECISIONS

Manufacturer 1 with quality \( u_1 \)

Manufacturer 2 with quality \( u_2 \)

\[ \vdots \]

Manufacturer \( n \) with quality \( u_n \) chooses...

- quantity \( Q_n \)
- compliance effort \( c_n \)
- testing \( t_{nm} \)

\[ \vdots \]

Manufacturer \( N \) with quality \( u_N \)

\[ \rho t_{Rn} \]

Regulator

utility units generate

social cost of noncompliance

\[ \rightarrow \] compliance effort cost

\[ \rightarrow \] testing cost