Quality in Supply Chain Encroachment

3 Model and Benchmark Analysis

3.1 Basic Model

$U(u, p; \theta) = \theta u - p$: Consumerm surplus

- $u > 0$: quality
- p: price
- $\theta \in [0, 1]$: sensitivity

$q = 1 - p/u$: demand

$p = u(1 - q)$: inverse demand function

ku^2: manufacturer unit cost

Timeline:

1. manufacturer decide u, w
2. retailer decide q_R
3. manufacturer decide q_M (if exists)

3.2 Benchmark: No Encroachment

We have:

$$\Pi_R^N(q_R, w, u) = (u(1 - q_R) - w) q_R$$

By maximize it, we have:

$$q_R^N(w, u) = \frac{1}{2} - w/(2u)$$

Then for manufacturer:

$\max_{w,u}\left(w-ku^2\right)q_R^N(w,u)=\max_{w,u}\left(w-ku^2\right)\left(\frac{1}{2}-\frac{w}{2u}\right)$

Then:

$w^N(u)=\frac{ku^2}{2}+\frac{u}{2}$

Then:

$\Pi_M^N(u)=\frac{u(1-ku)^2}{8}$ and $\Pi_R^N(u)=\frac{u(1-ku)^2}{16}$

Finally:

$\Pi_M^N=\frac{1}{54k}$ and $\Pi_R^N=\frac{1}{108k}$

4 Encroachment with Uniform Quality

4.1 Sequential Quantity Decisions

for manufacturer:

$\max_{q_M}\left\{\left(w-ku^2\right)q_R+\left(u-uq_M-uq_R-c-ku^2\right)q_M\right\}$

Then we get:

$q_M^u\left(q_R,w,u\right)=\left(\frac{1}{2}-q_R/2-c/(2u)-ku/2\right)^+$

Then for retailer:

$\max_{q_R}\left(u\left(1-q_R-q_M^U\left(q_R,w,u\right)\right)-w\right)q_R$

Then we get:

$$q_R^u(w,u)=\frac{1}{2}-\frac{w}{u}+\frac{ku}{2}+\frac{c}{2u} \quad \text{and}$$
$$q_M^u(w,u)=\frac{1}{4}+\frac{w}{2u}-\frac{3ku}{4}-\frac{3c}{4u}.$$

For manufacturer:

$$\max_{w,u}\left\{\left(w-ku^2\right)q_R^U(w,u)\right.$$
$$\left.+\left(u-uq_M^u(w,u)-uq_R^U(w,u)-c-ku^2\right)q_M^u(w,u)\right\}.$$

Then:

$w^U(u) = \frac{ku^2}{2} + \frac{u}{2} - \frac{c}{6}$

$$q_R^U\left(w^u(u), u\right) = \frac{2c}{3u} \text{ and}$$
$$q_M^U\left(w^U(u), u\right) = -\frac{ku}{2} - \frac{5c}{6u} + \frac{1}{2}.$$

Then:

$$\Pi_M^u(u) = \frac{k^2u^3}{4} + \frac{kcu}{2} + \frac{7c^2}{12u} - \frac{ku^2}{2} + \frac{u}{4} - \frac{c}{2} \quad \text{and}$$
$$\Pi_R^U(u) = \frac{2c^2}{9u}$$

Weg get, retailer is better off with encroachment if and only if:

$$\frac{3\left(u-ku^2\right)}{4\sqrt{2}} < c < \frac{3\left(u-ku^2\right)}{5}$$

Proposition 1

> (i) There exists a threshold $\tilde{c}$ such that the manufacturer encroaches if and only if $c < \tilde{c}$.
>
> (ii) Under encroachment, (a) the product quality u^u is first increasing and then decreasing in c, and (b) there exists a threshold c^u such that $u^U \geq u^N$, if $c \leq c^u$ and $u^U < u^N$ otherwise.
>
> (iii) When encroachment happens, the manufacturer always wins, $\Pi_M^U - \Pi_M^N > 0$, and the retailer always loses, $\Pi_R^U - \Pi_R^N < 0$.

4.2 Simultaneous quantity Decisions

Proposition 2

> (i) When both firms choose quantities simultaneously, there exists a threshold $\tilde{c}'$ such that the manufacturer encroaches if and only if $c < \tilde{c}'$. Under encroachment, there exists c_L such that the retailer always loses $\left(\Pi_R^S < \Pi_R^N\right)$, whereas the manufacturer loses $\left(\Pi_M^S < \Pi_M^N\right)$ if and only if $c_L < c < \tilde{c}'$. (ii) The manufacturer is more likely to encroach under simultaneous than under sequential quantity decisions: $\tilde{c} < \tilde{c}'$.

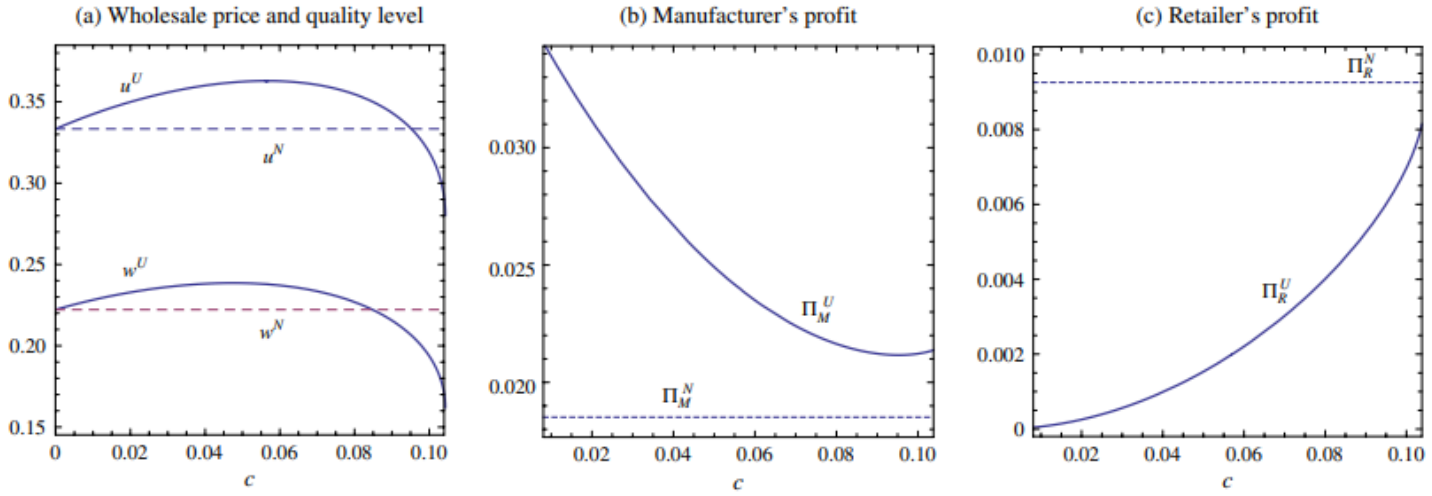


Figure 2 **(Color online) Firms' Profits vs. Cost of Quality k $(c = 1)$**

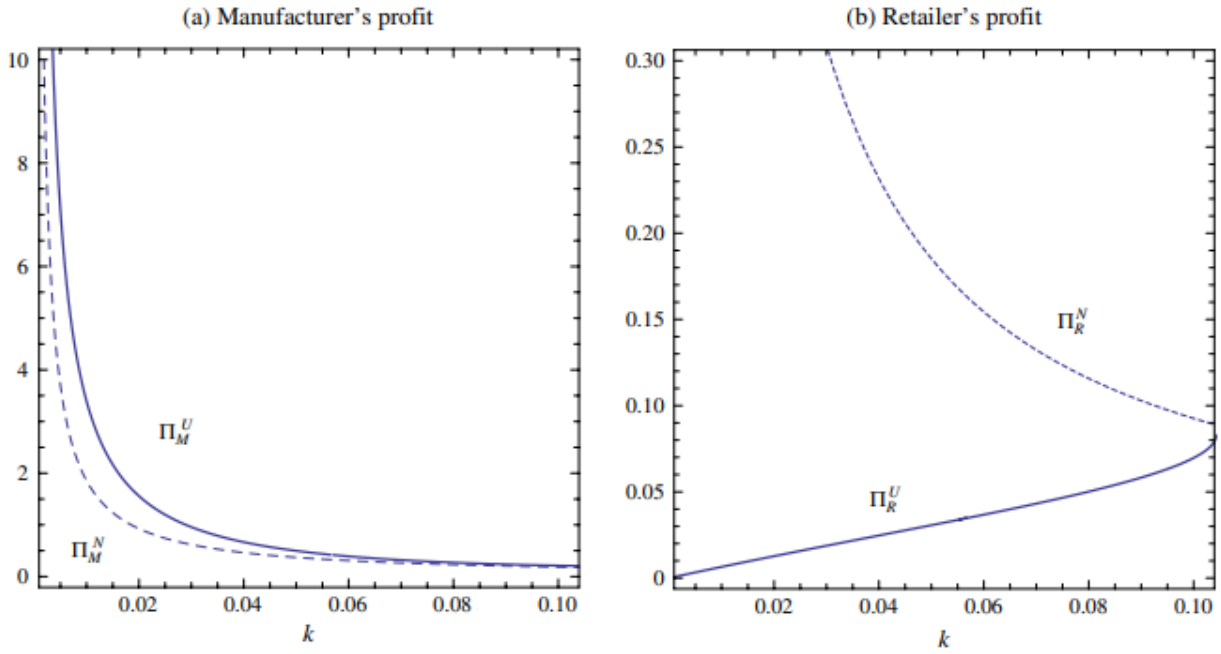
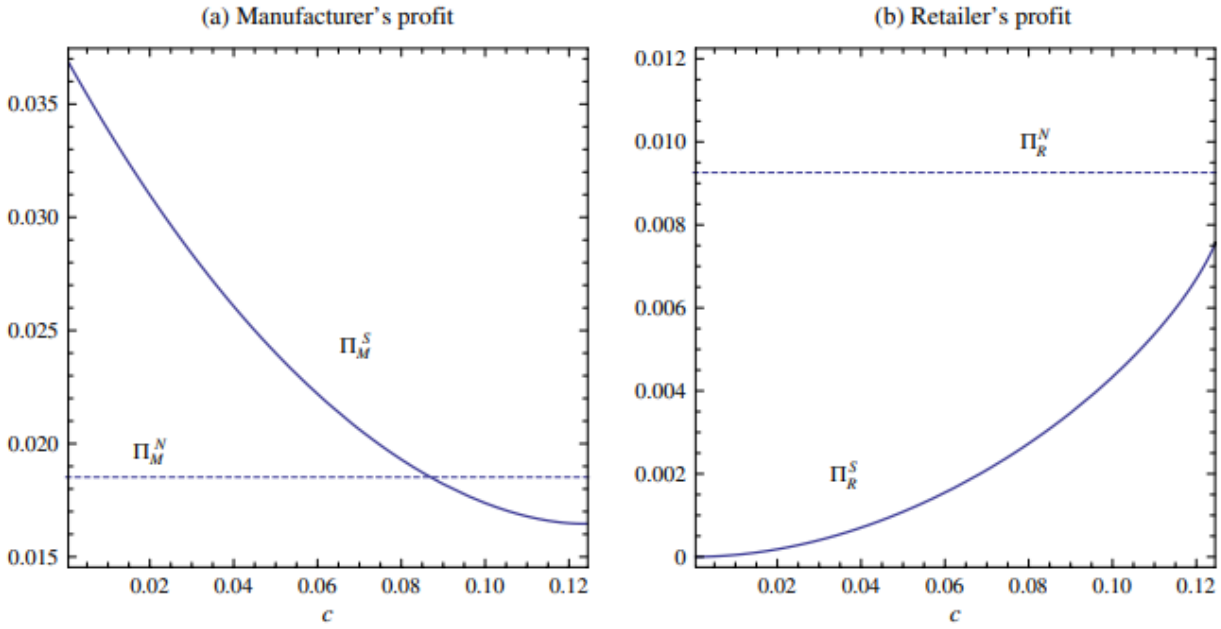


Figure 3 **(Color online) Comparison of Firms' Profits With and Without Encroachment Under Simultaneous Quantity Decisions** ($k = 1$)



5 Encroachment with Quality Differentiation

- u: direct channel
- $tu(t \in (0,1] or t \geq 1)$: indirect channel

Proposition 3

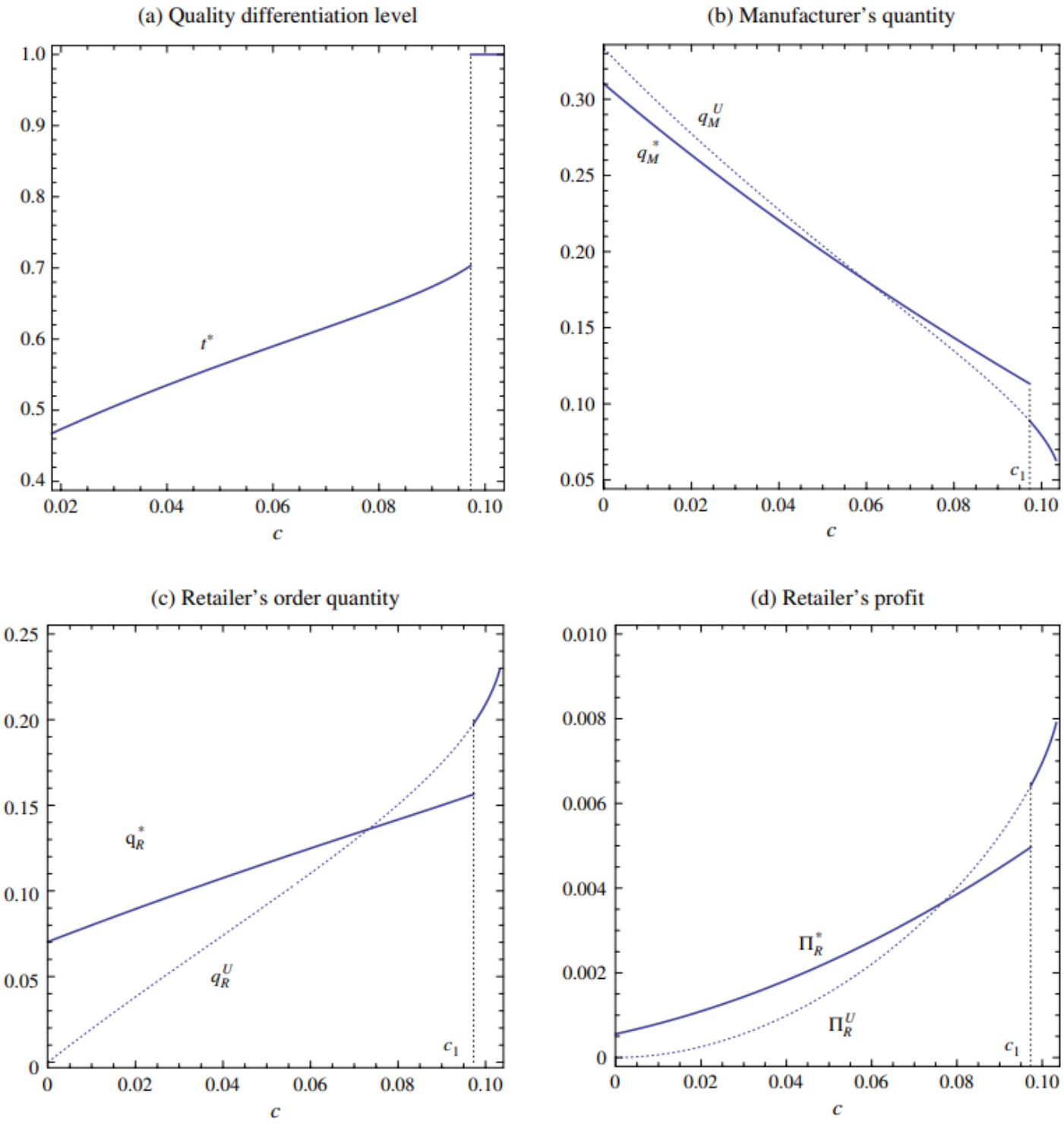
> Under encroachment, the manufacturer never offers a product of strictly lower quality through the direct channel.

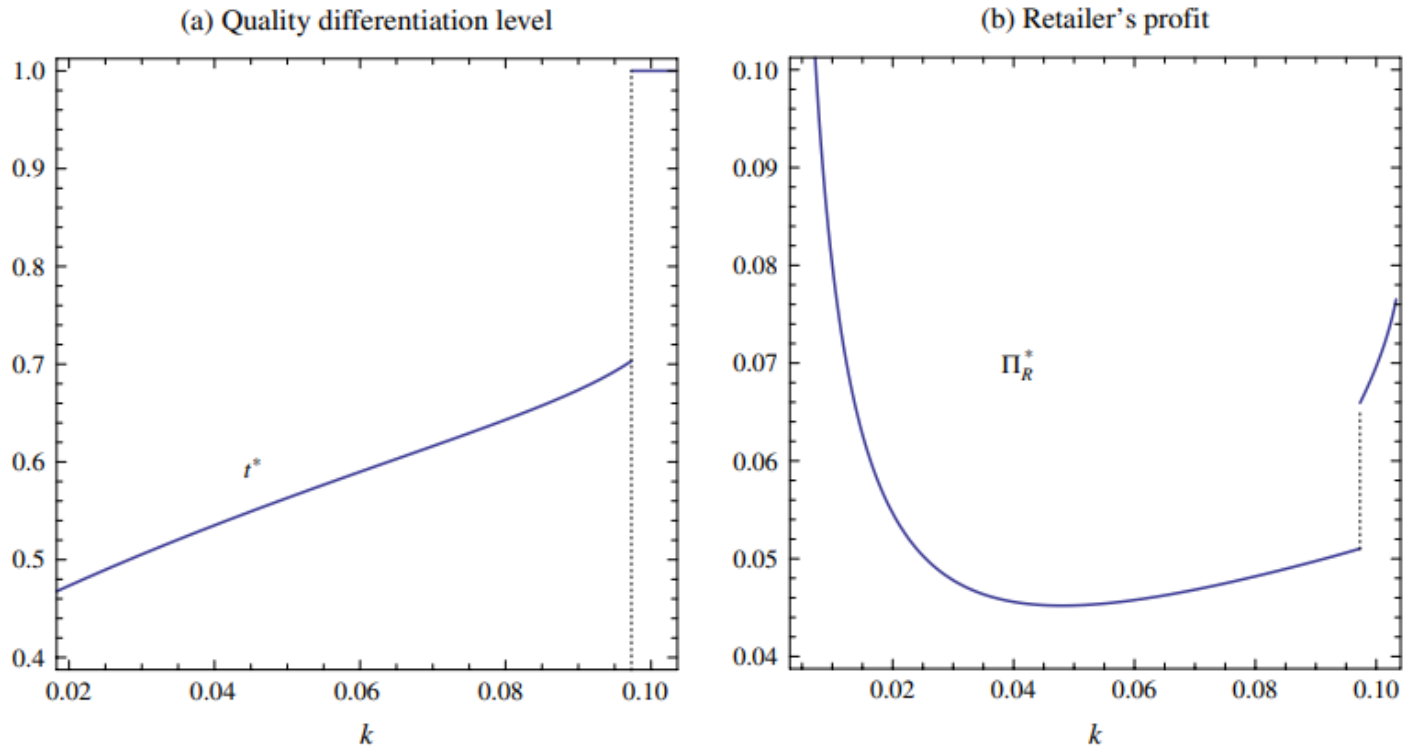
c	t^*	u^*	q_M^*
$0 \leq c < c_1$	$t^* = \frac{6}{5} - \frac{2}{5}\sqrt{4 - \frac{5c}{ku^{*2}}} < 1$	$u^* > \sqrt{\frac{4c}{3k}}$	$q_M^* > 0$
$c_1 < c \leq c_2$	$t^* = 1$	$u^* < \sqrt{\frac{4c}{3k}}$	$q_M^* > 0$
$c > c_2$	N/A	N/A	$q_M^* = 0$

Proposition 4

> (i) There exist two thresholds $c_1 < c_2$ that characterize the manufacturer's equilibrium decisions as given in Table 1.

(ii) When encroachment happens, the manufacturer always wins $\left(\Pi_M^* > \Pi_M^N\right)$ and the retailer always loses $\left(\Pi_R^* < \Pi_R^N\right)$.





Corollary 2

> Given $c > 0$, as k increases (i) the manufacturer becomes less likely to encroach or quality differentiate (i.e., both c_1 and c_2 decrease); and (ii) the retailer's profit first decreases and then increases.

6 Extension

6.1 Segmentation Through the Retailer

No direct channel, two product through retailer:

w_1, w_2, u_1, u_2

Proposition 5

> When encroachment happens, the manufacturer always wins $\left(\Pi_M^* - \Pi_M^{N2} > 0\right)$, and the retailer always loses $\left(\Pi_R^* - \Pi_R^{N2} < 0\right)$

6.2 Encroachment with Fixed cost of Quality

$\max(ku^2, kt^2u^2)$: fixed cost of quality

Proposition 6

> Under encroachment, (i) quality differentiation is not optimal (i.e., $t = 1$) and (ii) the manufacturer always wins and the retailer always loses.

6.3 No Quality Commitment for Direct Channel

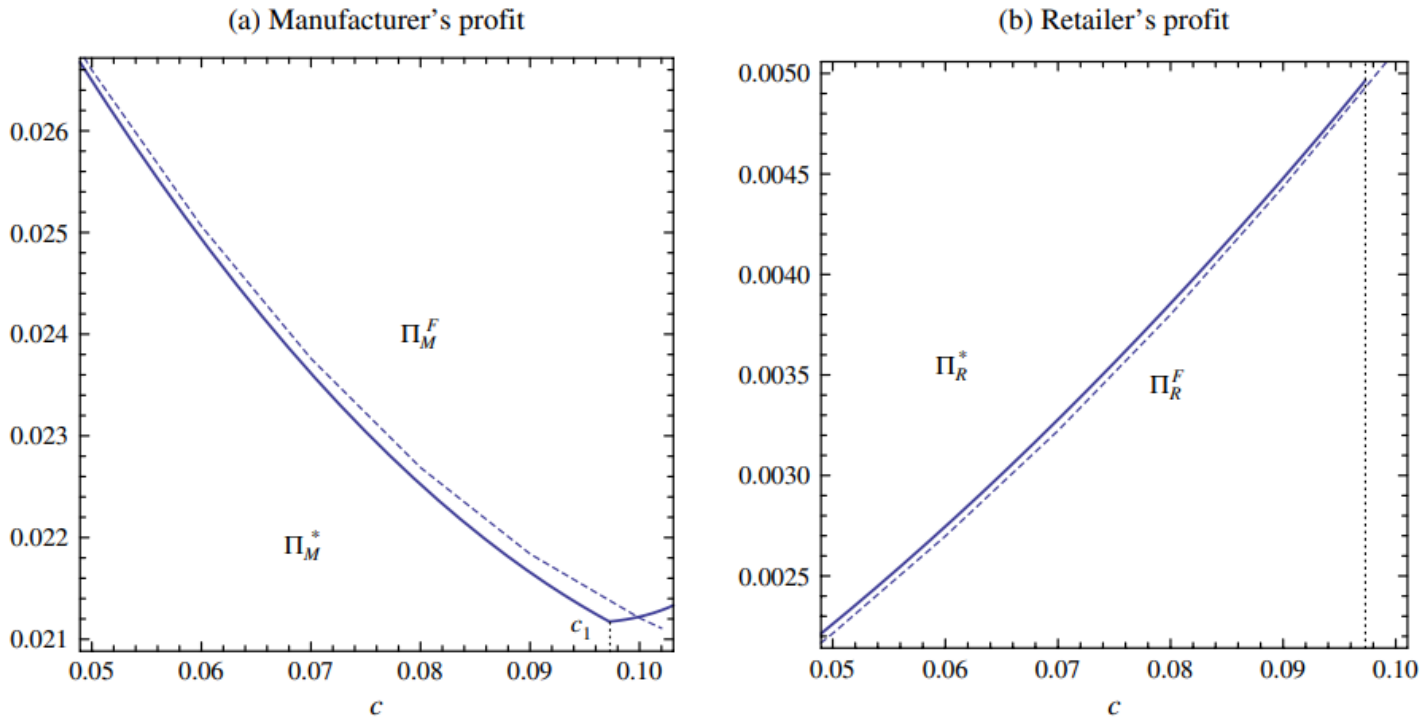
(i) the manufacturer announces the product quality u_R and the wholesale price w;

(ii) the retailer chooses the order quantity q_R;

(iii) the manufacturer determines the product quality u_M and selling quantity q_M.

Proposition 7

> If the encroaching manufacturer cannot commit to a level of quality in the direct-channel product, then quality differentiation across channels is always optimal.



6.4 Generalized Cost Function

$$\begin{cases} b & u \le u_0 \\ b + k(u - u_0)^2 & u > u_0 \end{cases}$$: unit cost

Proposition 8

> There exists a threshold $\bar{k} > 0$ such that
>
> (i) if $k \le \bar{k}$, then the retailer always loses from encroachment;
>
> (ii) if $k > \bar{k}$, then there exist $\underline{c}$ and $\bar{c}$ such that the retailer wins from encroachment when $\underline{c} < c < \bar{c}$.