International competition with non-linear pricing

Ngo Van Long
McGill University and CESifo

Frank Stähler
University of Tübingen, University of Adelaide and CESifo

Auckland, December 15, 2015

Empirical background I

- A large part of world trade is in intermediate goods which are used as an input into the production process, either to produce another intermediate good in the value chain or to produce a final good.
- Feenstra (1998), Feenstra and Hansen (1996): Substantial increase in vertical linkages across borders.
- Implication: increase in import competition for domestic suppliers.
- At the same time, the evidence how trade liberalization affects domestic firms is mixed.

Theory background I

- Most of the recent literature either considers a bilateral vertical partnership along the value chain, or assumes that independent suppliers have to apply a linear pricing scheme.
- But the marketing literature suggests that firms make use of non-linear pricing schemes very often, giving rise to a common agency problem.
  - Common agency with complete information and non-linear pricing: competition by menu auctions (Bernheim and Whinston, 1986) as used by Grossman and Helpman (1994) for their model of protection.
  - Problem: multiplicity of equilibria (Martimort, 2007); cannot account for potential firm heterogeneity (Melitz, 2003).
  - Here: incomplete information, decentralized contracting, private agency: contracts are offered (non-cooperatively) on different variables (inputs).

Our contribution I

- Starting point: no arbitrage/no secondary markets $\rightarrow$ firms can apply non-linear pricing schemes.
- Setup: competition between a domestic and a foreign upstream firm which serve a domestic downstream firm, incomplete information, no exclusion.
- Question: How does trade liberalization affect competition with non-linear pricing schemes?
- Result I: Trade liberalization changes both the linear components and the fixed fees in a particular way, but not the discount scheme.
- Result II: The domestic firm is more sensitive to the effects of trade liberalization under non-linear pricing compared to linear pricing.

Model setup I

- Two upstream firms: one domestic, labelled 1, with zero marginal costs, one foreign, labelled 2, with zero marginal costs + (not too large) trade cost t per unit.
- One (domestic) downstream firm facing an inverse demand function $p = a - \frac{b}{2}y$ for the final good, to be sold on an international market.
- The downstream firm needs an input q from at least one upstream supplier. One unit of input can be turned into one unit of output.
- Input will be acquired from the upstream firm(s). Additionally, processing the input requires an marginal cost ω_i per input unit q_i by the downstream firm. Furthermore, combining both inputs leads to a cost reduction such that the downstream processing costs are given by

$$\omega_1 q_1 + \omega_2 q_2 - \mu q_1 q_2.$$

with $b > \mu > 0$.

Model setup II

- μ is common knowledge.
- $b > \mu$ also ensures that the downstream firm's profit function is concave in (q_1, q_2).
- $\{\omega_1, \omega_2\}$ is private information of the downstream firm.
- Redefine private information as $\theta_i = a - \omega_i$.
- The upstream firms and the downstream firm play a two-stage game: (i) linear or non-linear pricing schemes, (ii) downstream demand.

Assumption

$$\underline{\theta} > \max\left(\frac{b-\mu}{b}\overline{\theta} + t, \frac{r(3-2r)}{2-r^2}\overline{\theta} + \frac{1}{2+r}t\right)$$

$$\textit{where } 0 < r \equiv \frac{4(b-\mu)}{b + \sqrt{b^2 + 8(b-\mu)}} < 1.$$

Model setup III

- This assumption will guarantee that the demand for each input will be positive, both in the case of linear pricing and in the case of non-linear pricing by the upstream firms.
- We solve for the Bayesian Nash equilibrium in linear versus non-linear prices.

Linear pricing I

- Downstream profit function is given by

$$\Pi = v(\theta_1, \theta_2, q_1, q_2) - p_1 q_1 - p_2 q_2$$

where

$$v(\theta_1, \theta_2, q_1, q_2) = \theta_1 q_1 + \theta_2 q_2 - \frac{b}{2} q_1^2 - \frac{b}{2} q_2^2 - (b - \mu) q_1 q_2$$

- Upstream firms form expectations on the downstream firm's type: $\theta_i \in \left[\underline{\theta}, \overline{\theta}\right]$ and the productivities (θ_1, θ_2) are independently drawn from the same distribution $f(\theta_i)$. $\hat{\theta} = \int_{\underline{\theta}}^{\overline{\theta}} \theta f(\theta) d\theta \rightarrow$ expected demands.
- Optimal prices:

$$p_1 = \frac{\hat{\theta}(3b - \mu)\mu + b(b - \mu)t}{(3b - \mu)(b + \mu)}, p_2 = \frac{\hat{\theta}(3b - \mu)\mu + 2b^2 t}{(3b - \mu)(b + \mu)}.$$

Linear pricing II

- Both prices decline with a decline in $t \rightarrow$ prices are strategic complements. The effect is stronger for the foreign firm.
- The demand for the foreign input rises and the demand for domestic input declines.
- δ: the marginal change in domestic production per marginal change of foreign production for the case of linear pricing, measures the sensitivity of domestic production to a change in foreign production due to trade liberalization.

$$\delta = -\frac{dq_1}{dq_2} = \frac{b-\mu}{b+\mu}.$$

- Trade liberalization will unambiguously reduce the domestic supplier's profits. Ambiguous effect on the foreign supplier: (i) direct effect: cost reduction, (ii) strategic effect: domestic price reduction.

Linear pricing III

- Note: an increase in downstream firm heterogeneity, measured by a mean-preserving spread of θ_i, does not change the pricing behavior of firms.

Non-linear pricing I

- Each firm i $(i = 1, 2)$ offers a *schedule* $T_i(q_i)$ to the downstream firm $\rightarrow$ common agency problem under adverse selection in which the upstream firms are the principals and the downstream firm is the common agent.
- Downstream profit function:

$$\Pi = \theta_1 q_1 + \theta_2 q_2 - \frac{b}{2} q_1^2 - \frac{b}{2} q_2^2 - (b - \mu) q_1 q_2 - T_1(q_1) - T_2(q_2).$$

- The Revelation Principle can be applied after a transformation of variables.
- Suppose firm 2's schedule is

$$T_2(q_2) = \underbrace{\gamma_2}_{\text{fixed fee}} + \underbrace{\alpha_2 q_2}_{\text{linear component}} + \underbrace{\frac{\beta_2}{2} q_2^2}_{\text{discount}}$$

Non-linear pricing II

- What is firm 1's best reply to this schedule?
- Firm 1 can deduce that the downstream firm's choice of q_1 and q_2 must satisfy:

$$\theta_2 - \alpha_2 = (b + \beta_2)q_2 + (b - \mu)q_1,$$

$$\theta_1 = bq_1 + (b - \mu)q_2 + T_1'(q_1).$$

- By substitution, we obtain

$$\theta_1 - \frac{(b-\mu)\theta_2}{b+\beta_2} + \frac{(b-\mu)\alpha_2}{b+\beta_2} = \left(b - \frac{(b-\mu)^2}{b+\beta_2}\right) q_1 + T_1'(q_1).$$

Non-linear pricing III

- Firm 1 can now think of the downstream firm as being characterized by a sufficient statistic z_1 defined by

$$z_1 \equiv \theta_1 - \frac{(b-\mu)\theta_2}{b+\beta_2}.$$

- We can now solve for the function $T_1(.)$ using the Revelation Principle, where the agent is characterized by z_1 and the distribution of z_1 is known.
- Note: β_i is endogenous. However, we will find that this will not play any role for our comparative statics exercises.
- z_i is distributed between $\underline{z}$ and $\overline{z}$ where

$$\underline{z} = \underline{\theta} - \frac{b-\mu}{b+\beta_{-i}}\overline{\theta}, \overline{z} = \overline{\theta} - \frac{b-\mu}{b+\beta_{-i}}\underline{\theta}.$$

- The worst realization is thus given by $\underline{z}$.

Non-linear pricing IV

- Question: How do we determine the fixed fees?
- Answer: The relevant participation constraint – due to $b - \mu > 0$ – is the outside option to source only from one firm. Hence, the least efficient downstream firm, that is, the one with the worst realization, must be held up from sourcing from only one firm.

Non-linear pricing V

Proposition

Assume that z_i is uniformly distributed according to the c.d.f. $G(z_i) = (z_i - \underline{z})/(\overline{z} - \underline{z})$. Equilibrium pricing schemes exist which are linear-quadratic and concave, giving a discount for larger orders. Each upstream supplier offers $T_i = \gamma_i + \alpha_i q_i + \frac{\beta_i}{2} q_i^2$ where the equilibrium parameters are as follows.

$$\beta_i = \beta = \frac{b}{4}\left[\sqrt{1 + 8\frac{(b-\mu)^2}{b^2}} - 3\right] < 0, 0 < r \equiv \frac{b-\mu}{b+\beta} < 1,$$

$$\alpha_1 = \frac{1}{4 - r^2}\left[(2 + r)\,\overline{z} + rt\right], \alpha_2 = \frac{1}{4 - r^2}\left[(2 + r)\,\overline{z} + 2t\right],$$

$$\gamma_i = \frac{-\beta}{2}\left[q_i(\underline{z})\right]^2 > 0, q_i(z) > 0 \forall z \in [\underline{z}, \overline{z}].$$

Non-linear pricing VI

- Important properties of the non-linear pricing scheme:
  - Changes in the marginal/ trade costs or in the bounds $\underline{z}$ and $\overline{z}$ have no impact on β_i.
  - $\beta_i = \beta < 0$: (i) transfer scheme is regressive in outputs, (ii) equilibrium discount is the same for both firms.
  - If the opponent's linear component α_{-i} increases, the fixed fee γ_i will increase, but neither the linear component α_i nor the discount β are modified.

Trade liberalization and non-linear pricing I

Lemma

Trade liberalization does not change the regressive part of the pricing schemes, but (i) decreases the linear part of both pricing schemes, (ii) leads to a reduction in the domestic fixed fee, and an increase in the foreign fixed fee. Domestic input demand decreases and foreign input demand increases.

Δ: the marginal change in domestic production per marginal change of foreign production for the case of non-linear pricing, measures the sensitivity of domestic production to a change in foreign production due to trade liberalization.

$$\Delta = -\frac{dq_1}{dq_2} = \frac{r}{2 - r^2}.$$

Trade liberalization and non-linear pricing II

Proposition

$\Delta > \delta$: The sensitivity of domestic production to changes in foreign production is larger under non-linear pricing than under linear pricing.

- Trade liberalization reduces the expected sales and the profit of the domestic upstream firm.
- The effect on foreign upstream profits is not ambiguous: the decrease in trade costs increases foreign sales and profits. Why?
  - The foreign supplier benefits also through an increase in the fixed fee.
  - Thus, the foreign supplier can appropriate liberalization profits with less distortions in input demand than in the case of linear pricing.
  - Consequently the sensitivity of domestic firms becomes larger as its foreign rival can benefit stronger from an increase in foreign input demand.

The role of downstream firm heterogeneity I

What is the role of downstream firm heterogeneity?

Proposition

An increase in downstream firm heterogeneity, measured by a mean-preserving spread, does not change the regressive part of the pricing schemes, but (i) increases the linear component of both pricing schemes (ii) and leads to a reduction in the both the domestic and the foreign fixed fee.

- Principal-agent relationship: both firms compete for input demand, but at the same time, the combination of a discount scheme and a fixed fee allows them to reap some of the downstream firm's profits.

The role of downstream firm heterogeneity II

- The least productive type determines the fixed fee as this type must be held back from sourcing from a single supplier only. A mean-preserving spread makes the least productive type less productive, so the fixed fee must fall.
- The rent at the high end of the distribution increases with a mean-preserving spread, because the most productive types will receive a larger discount. The increase in the linear component should compensate for the necessary reduction in the fixed fee in order to appropriate a part of the increased profits of the most productive types.

Possible extensions

- Consider exclusion.
- How would a firm want to organize its national and international activities, not knowing the input productivities?
- Firms could also be divisions within a multinational firm: outsourcing versus integration, information asymmetries also within a firm (similar to holdup-problems as in Antràs, 2003), outsourcing works like a mean-preserving spread.
- Suppose that the domestic upstream supplier is a division of the firm:
  - Should the firm allow competition between the two suppliers?
  - Should the firm allow only linear pricing of the domestic supplier?
- The model is strategically equivalent to a model in which two suppliers compete in a market where (i) demand is given by a representative consumer with linear-quadratic preferences and (ii) the preference parameters are not known.

Concluding remarks

- Empirical evidence suggests that non-linear pricing schemes play an important role in vertical relationships.
- We have employed a model with international upstream competition and downstream private information which leads to non-linear pricing.
- The sensitivity of domestic input demand to a change in foreign input demand is larger under non-linear pricing: the foreign supplier has more options to appropriate the benefits from trade liberalization.
- Channel that determines the vulnerability of a domestic industry to trade liberalization:
  - If an industry is part of a vertical structure in a global value chain and produces customized inputs (non-linear pricing is possible): larger vulnerability to trade liberalization.
  - If arbitrage is possible (implying linear pricing), we expect a lower vulnerability to trade liberalization.