Discussion Papers
Collana di
E-papers del Dipartimento di Economia e Management – Università di Pisa

Luciano Fanti and Luca Gori

Product innovation and two-part tariff vertical contracts

Discussion Paper n. 222
2017

Discussion Paper n. 222, presentato: **settembre 2017**

Corresponding Authors:

L. Fanti, Department of Economics and Management, University of Pisa, Via Cosimo Ridolfi, 10, I–56124 Pisa (PI), Italy; e-mail: luciano.fanti@unipi.it

L. Gori (corresponding author), Department of Political Science, University of Genoa, Via Balbi, 30/19, I–16126 Genoa (GE), Italy; e-mail: luca.gori@unige.it or dr.luca.gori@gmail.com

Please quote as follows:

Luciano Fanti and Luca Gori (2017), "Product innovation and two-part tariff vertical contracts", Discussion Papers del Dipartimento di Economia e Management – Università di Pisa, n. 222 (http://www.ec.unipi.it/ricerca/discussion-papers.html).

Discussion Paper
n. 222

Luciano Fanti and Luca Gori

Product innovation and two-part tariff vertical contracts

Abstract

This article studies the effects of R&D investments in product innovation in a game-theoretic two-tier model where an upstream monopolist and downstream duopolists negotiate over the terms of a non-linear two-part tariff vertical contract.

Keywords Duopoly; Product innovation; Two-part tariffs

JEL Classification D43; L13; L14

1. Introduction

Although the existing literature on investments in R&D activity is vast, a few contributions analyse R&D efforts aimed at product innovation in a game-theoretic context (e.g., Lambertini and Rossini, 1998; Lin and Saggi, 2002). However, R&D expenditures related to product innovation are maybe more common than those related to costs reductions (Scherer and Ross, 1990).

On another side, a well-established line of research analysed the working of vertically related markets, focusing on the more typical ways of trading amongst vertically related firms. In particular, a widespread contract in a two-tier market through which an upstream monopolist trades with two downstream duopolists is a non-linear two-part tariff contract (for empirical evidence, see Villas-Boas, 2007). Since Hart and Tirole (1990), several studies concentrate on the features of this kind of contract (for instance, Alipranti et al., 2014; Basak and Wang, 2016, to cite only the more recent works). In particular, Alipranti at al. (2014) investigate the relationship between this kind of contract and the profitability of quantity and price competition firms, whereas Basak and Wang (2016) deals with the endogenous choice of the mode of competition by downstream firms.

A non-linear two-part tariff contract may be stipulated through two distinct kinds of negotiations between the upstream monopolist and downstream duopolists, leading to different outcomes of the underlying game between bargainers (Horn and Wolinski, 1988): a joint (resp. separate) bargaining with both (resp. each) downstream firms' delegates (resp. firm's delegate), where the contract terms are (resp. are not) publicly observable.

However, to the best of our knowledge, there do not exist studies combining the relationship between these typologies of contracts in a two-tier industry and the incentive to innovate products in a game-theoretic model. This work aims at filling this gap. In this regard, two main questions arise. 1) Is the willingness to invest in product differentiation in a two-tier market larger or smaller than in a one-tier market? 2) Do the likelihood of investing in product innovation increase or decrease when the supplier bargain secretly or publicly with both customers? Depending on the mode of competition, the relative bargaining power of the monopolist and the effectiveness of R&D effort, this widespread kind of vertical contract produces several effects on product innovation. The work extends the literature on product innovation R&D to a vertically related industry.

The rest of the article proceeds as follows. Section 2 sets up the model and details the main results. Section 3 concludes.

2. The model set-up

Consider a two-tier industry comprised of one upstream monopolist U and two downstream firms D_i and D_j, $i = \{1,2\}, i \neq j$ (Milliou and Petrakis, 2007; Alipranti et al., 2014; Basak and Wang, 2016). Production of U implies a constant marginal cost $0 \le c < 1$. There is a one-to-one relationship between products of U and D_i (e.g., between inputs and final product) and an exclusive relationship between U and D_i. Each D_i faces a linear inverse (resp. direct) demand function

$$p_i = 1 - q_i - d q_j \quad \text{(resp. } q_i = \frac{1}{1+d} - \frac{p_i}{1-d^2} + \frac{dp_j}{1-d^2}\text{)}, \tag{1}$$

where $i = \{1,2\}$, $i \neq j$, and $0 \le d \le 1$ is the extent of horizontal product substitutability.

Negotiations between U and each D_i are conducted over a non-linear two-part tariff contract, including a wholesale price $w_i > 0$ and a fixed fee T_i.[1] These negotiations are modelled as a generalised Nash bargaining problem, where b ($0 \le b \le 1$) is the relative bargaining power of U. The whole game is solved by deriving its subgame perfect equilibrium.

Profits of U and D_i are:

$$\Pi^U = (w_i q_i - c + T_i) + (w_j q_j - c + T_j), \tag{2}$$

and

$$\Pi_i^D = (p_i - w_i) q_i - T_i, \tag{3}$$

We consider two distinct kinds of negotiations between U and D_i.

Case J. U *jointly* bargains with delegates of both D_i and D_j over the terms of a two-part tariff contract. For doing this, U maximises Nash product (4) below with respect to the fixed fee and (after substitution of this optimal value in (4)), it maximises again the function with respect to wholesale prices. This amounts to maximise joint profits of the vertical industry (that is, the sum of profits of monopolist and downstream firms). Consequently, output and profits are the same irrespective of the mode of competition in the final market.

Case S. U *separately* bargains with the delegate of each D_i. Each of the bargainers takes as given the outcome of the simultaneous (separate) negotiations of U and D_i. Therefore, a disagreement pay-off emerges. It is given by monopolist's profits when negotiations with D_i break down and D_j acts as a monopolist in the downstream market. Then, there exists an incentive to free ride. Therefore, each D_i may form multiple beliefs with respect to the out-of-equilibrium offers and thus multiple equilibria can arise. To prevent this, the restriction $b > \bar{b}(d^{\circ\circ}) := \frac{(d^{\circ\circ})^3}{(2-d^{\circ\circ})[2-(d^{\circ\circ})^2]}$ should hold, where $\bar{b}(d^{\circ\circ}) \in (0,1)$ for any $d^{\circ\circ} \in (0,1)$. See Milliou and Petrakis (2007, p. 970) and Aliprantı et al. (2014, p. 123) for details.

The following Nash products resume the distinctive features of these modes of negotiations:

[1] Negative fixed-fees could occur. In this case, the upstream firm "subsidises" downstream firms' production.

$$N^J = \left[\sum_{i=1}^{2}\Pi_i^U\right]^b \left[\sum_{i=1}^{2}(\Pi_i^D - T_i)\right]^{1-b}, \tag{4}$$

and

$$N_i^S = (\Pi_i^U - t^S)^b(\Pi_i^D)^{1-b}, \tag{5}$$

where $t^S = (w_j^M - c)\left(\frac{1-w_j^M}{2}\right)$ is the disagreement payoff of U if D_j acts as a downstream monopolist (M) in the final market facing input price w_j^M.

Strategies of investing (I) and not investing (NI) a fixed monetary amount ($F > 0$) to differentiate products at R&D stage are common knowledge. Products become highly heterogeneous ($d = d^\circ$) [resp. homogeneous ($d = 1$)] if both firms invest [resp. do not invest] in R&D. Products are scarcely heterogeneous ($d = d^{\circ\circ}$) if only one firm invests ($0 \le d^\circ < d^{\circ\circ} < 1$).

Standard calculations[2] lead to the following equilibrium values of profits of downstream firms.

Case J. The subscript $k = \{C, B\}$ refers to Cournot and Bertrand.

$$\begin{aligned} {}^J\Pi_{i,k}^{NI/NI}\Big|_{d=1} &= \frac{1-b}{8}, \quad {}^J\Pi_{i,k}^{NI/I} = \frac{1-b}{4(1+d^{\circ\circ})}, \\ {}^J\Pi_{i,k}^{I/NI} &= \frac{1-b}{4(1+d^{\circ\circ})} - F, \quad {}^J\Pi_{i,k}^{I/I} = \frac{1-b}{4(1+d^{\circ})} - F, \end{aligned} \tag{6}$$

Case S. Cournot.

$$\begin{aligned} {}^S\Pi_{i,C}^{NI/NI}\Big|_{d=1} &= \frac{1-b}{8}, \quad {}^S\Pi_{i,C}^{NI/I} = \frac{(1-b)(2-d^{\circ\circ})^2}{8[2-(d^{\circ\circ})^2]}, \\ {}^S\Pi_{i,C}^{I/NI} &= \frac{(1-b)(2-d^{\circ\circ})^2}{8[2-(d^{\circ\circ})^2]} - F, \quad {}^S\Pi_{i,C}^{I/I} = \frac{(1-b)(2-d^{\circ})^2}{8[2-(d^{\circ})^2]} - F, \end{aligned} \tag{7}$$

Case S. Bertrand.

$$\begin{aligned} {}^S\Pi_{i,B}^{NI/NI}\Big|_{d=1} &= \frac{3(1-b)}{32}, \quad {}^S\Pi_{i,B}^{NI/I} = \frac{(1-b)(2+d^{\circ\circ})[4-2d^{\circ\circ}-(d^{\circ\circ})^3+(d^{\circ\circ})^4]}{32(1+d^{\circ\circ})}, \\ {}^S\Pi_{i,B}^{I/NI} &= \frac{(1-b)(2+d^{\circ\circ})[4-2d^{\circ\circ}-(d^{\circ\circ})^3+(d^{\circ\circ})^4]}{32(1+d^{\circ\circ})} - F, \\ {}^S\Pi_{i,B}^{I/I} &= \frac{(1-b)(2+d^{\circ})[4-2d^{\circ}-(d^{\circ})^3+(d^{\circ})^4]}{32(1+d^{\circ})} - F, \end{aligned} \tag{8}$$

Let ${}^y\Delta_1^k := {}^y\Pi_{i,k}^{I/NI} - {}^y\Pi_{i,k}^{NI/NI}$, ${}^y\Delta_2^k := {}^y\Pi_{i,k}^{NI/I} - {}^y\Pi_{i,k}^{I/I}$, ${}^y\Delta_3^k := {}^y\Pi_{i,k}^{NI/NI} - {}^y\Pi_{i,k}^{I/I}$ be profit differentials and ${}^yF_x^k \Rightarrow {}^y\Delta_x^k = 0$ the corresponding threshold curves ($i = \{1,2\}$, $x = \{1,2,3\}$, $y = \{J, S\}$, $k = \{C, B\}$). In particular,

$${}^JF_1^k := \frac{(1-b)(1-d^{\circ\circ})}{8(1+d^{\circ\circ})} > 0, \quad {}^JF_2^k := \frac{(1-b)(d^{\circ\circ}-d^{\circ})}{4(1+d^{\circ})(1+d^{\circ\circ})} > 0, \quad {}^JF_3^k := \frac{(1-b)(1-d^{\circ})}{8(1+d^{\circ})} > 0,$$

[2] See Basak and Wang (2016) for mode J, and Milliou and Petrakis (2007) and Alipranti et al. (2014) for mode S.

$$ {}^{S}F_1^C := \frac{(1-b)(1-d^{\circ\circ})[5+2d^{\circ\circ}-2(d^{\circ\circ})^3-(d^{\circ\circ})^4]}{32(1+d^{\circ\circ})} > 0, $$

$$ {}^{S}F_2^C := \frac{(1-b)(d^{\circ\circ}-d^{\circ})}{32(1+d^{\circ})(1+d^{\circ\circ})} \times $$
$$ \times \big[8+2d^{\circ}+2d^{\circ\circ}+2(d^{\circ})^2+2(d^{\circ\circ})^2+4d^{\circ}d^{\circ\circ}+(d^{\circ})^2d^{\circ\circ}+d^{\circ}(d^{\circ\circ})^2-(d^{\circ\circ})^4-(d^{\circ\circ})^3-(d^{\circ})^4- $$
$$ -(d^{\circ})^3-d^{\circ}(d^{\circ\circ})^4-(d^{\circ})^2(d^{\circ\circ})^3-(d^{\circ})^3(d^{\circ\circ})^2-(d^{\circ})^4d^{\circ\circ}-2d^{\circ}(d^{\circ\circ})^3-2(d^{\circ})^2(d^{\circ\circ})^2-2(d^{\circ})^3d^{\circ\circ}\big] > 0 $$

$$ {}^{S}F_3^C := \frac{(1-b)(1-d^{\circ})[5+2d^{\circ}-2(d^{\circ})^3-(d^{\circ})^4]}{32(1+d^{\circ})} > 0, $$
$$ {}^{S}F_1^B := \frac{(1-b)(1-d^{\circ\circ})^2}{4[2-(d^{\circ\circ})^2]} > 0, $$
$$ {}^{S}F_2^B := \frac{(1-b)(d^{\circ\circ}-d^{\circ})[4+2d^{\circ}d^{\circ\circ}-3d^{\circ}-3d^{\circ\circ}]}{4[2-(d^{\circ})^2][2-(d^{\circ\circ})^2]} > 0, $$
$$ {}^{S}F_3^B := \frac{(1-b)(1-d^{\circ})^2}{4[2-(d^{\circ})^2]} > 0, $$

Define the following threshold curves related to a one-tier industry, as developed by Lambertini and Rossini (1998) and Bernhofen and Bernhofen (1999) (LR and BB henceforth), which will be useful for comparison purposes:

$$ {}^{LR}F_1^C := \frac{(5+d^{\circ\circ})(1-d^{\circ\circ})}{9(2+d^{\circ\circ})^2} > 0, \qquad {}^{LR}F_2^C := \frac{(d^{\circ\circ}-d^{\circ})(4+d^{\circ}+d^{\circ\circ})}{(2+d^{\circ})^2(2+d^{\circ\circ})^2} > 0, $$
$$ {}^{LR}F_3^C := \frac{(5+d^{\circ})(1-d^{\circ})}{9(2+d^{\circ})^2} > 0, $$

and

$$ {}^{LR}F_1^B := \frac{1-d^{\circ\circ}}{(1+d^{\circ\circ})(2-d^{\circ\circ})^2} > 0, \quad {}^{LR}F_3^B := \frac{1-d^{\circ}}{(1+d^{\circ})(2-d^{\circ})^2} > 0, $$
$$ {}^{LR}F_2^B := \frac{(d^{\circ\circ}-d^{\circ})[4-3(d^{\circ\circ}+d^{\circ})+(d^{\circ})^2(1-d^{\circ\circ})+(d^{\circ\circ})^2(1-d^{\circ})]}{(1+d^{\circ})(2-d^{\circ})^2(1+d^{\circ\circ})(2-d^{\circ\circ})^2} > 0. $$

The main findings of the article are summarised in the following propositions and results.

Proposition 1. [S and J]. In a two-tier industry, equilibrium outcomes under modes J and S in $(d^{\circ\circ}, F)$ space for any b and d° (resp. $\bar{b}(d^{\circ\circ}) < b \le 1$ and d°) are:

I. ${}^{y}\Delta_1^k < 0,\ {}^{y}\Delta_2^k > 0,\ {}^{y}\Delta_3^k < 0$. One (Pareto inefficient) Nash equilibrium (NI,NI).
II. ${}^{y}\Delta_1^k < 0,\ {}^{y}\Delta_2^k < 0,\ {}^{y}\Delta_3^k < 0$. Two Nash equilibria (NI,NI) and (I,I). I payoff dominates NI.
III. ${}^{y}\Delta_1^k > 0,\ {}^{y}\Delta_2^k < 0,\ {}^{y}\Delta_3^k < 0$. One (Pareto efficient) Nash equilibrium (I,I).
IV. ${}^{y}\Delta_1^k > 0,\ {}^{y}\Delta_2^k > 0,\ {}^{y}\Delta_3^k < 0$. Two (Pareto efficient) asymmetric Nash equilibria (NI,I) and (I,NI).
V. ${}^{y}\Delta_1^k < 0,\ {}^{y}\Delta_2^k > 0,\ {}^{y}\Delta_3^k > 0$. One (Pareto efficient) Nash equilibrium (NI,NI).

Proof. Results follow by the sign of profit differentials. **Q.E.D.**

Figure 1 (resp. Figures 2 and 3) illustrates (resp. illustrate) Proposition 1 for Case J (resp. S). Different from a one-tier model outlined by LR and BB, and revisited by Fanti and Gori (2016), in a two-tier industry a prisoner's dilemma with homogeneous products exists also in the Bertrand game. This is because the relative bargaining power b allows downstream firms to get positive profits also in the case of homogeneous product and the upstream firm to extract rents from downstream product investments.

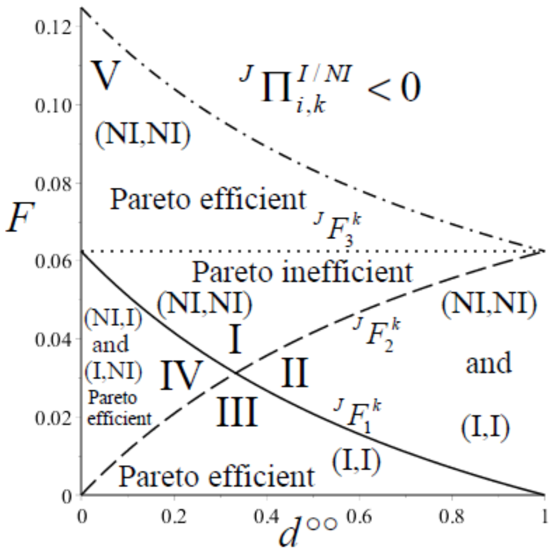

Figure 1. [J]. Equilibrium outcomes ($b = 0.5$, $d^{\circ} = 0$).

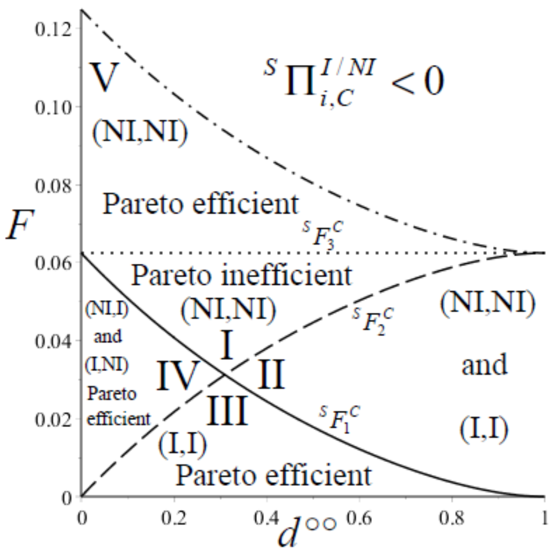

Figure 2. [S – Cournot]. Equilibrium outcomes ($b = 0.5$, $d^{\circ} = 0$).

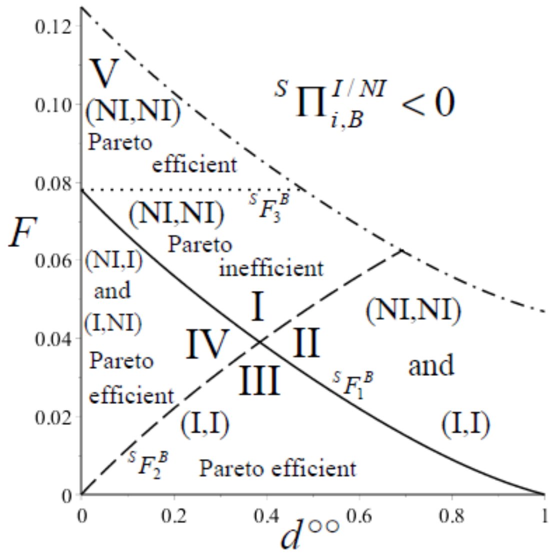

Figure 3. [S – Bertrand]. Equilibrium outcomes ($b = 0.5$, $d^{\circ} = 0$).

Proposition 2. [J]. Under mode J, the likelihood of (I,I) in a two-tier industry is smaller than in a one-tier Cournot or Bertrand market.

Proof. As ${}^{J}Z_1^C := {}^{J}F_1^C - {}^{LR}F_1^C < 0$, ${}^{J}Z_2^C := {}^{J}F_2^C - {}^{LR}F_2^C < 0$, ${}^{J}Z_1^B := {}^{J}F_1^B - {}^{LR}F_1^B < 0$, ${}^{J}Z_1^B := {}^{J}F_1^B - {}^{LR}F_1^B < 0$ for any $0 \le b \le 1$ and d°, and $\partial {}^{J}F_x^k / \partial b < 0$, the result follows. **Q.E.D.**

Result 1. [S]. Let ${}^{S}Z_x^k := {}^{S}F_x^k - {}^{LR}F_x^k$ ($k = \{C, B\}$, $x = \{1,2,3\}$). Under mode S, the likelihood of (I,I) in a two-tier industry can be larger or smaller (resp. is smaller) than in a one-tier Cournot (resp. Bertrand) market for any $\bar{b}(d^{\circ\circ}) < b \le 1$ and $0 \le d^{\circ} < d^{\circ\circ} < 1$.

This result is illustrated in Figure 4 (resp. 5) for a Cournot (resp. Bertrand) game in the case of maximal effectiveness of product R&D investment ($d^{\circ} = 0$). The figures qualitatively hold also for the other values of the extent of product differentiation. On the one hand, the result that in a two-tier industry firms have a smaller incentive to invest in product R&D is reminiscent of the well-known "hold-up" problem arising when firms invest in cost-reducing R&D in the presence of unions (because they capture part of the gains of innovations) (Grout, 1984). On the other hand, the result that with quantity-setting (and, of course, small supplier's power) the incentive may be increased, in contrast with the "hold-up" argument, reveals a so far not explored feature of a two-part tariff contract.

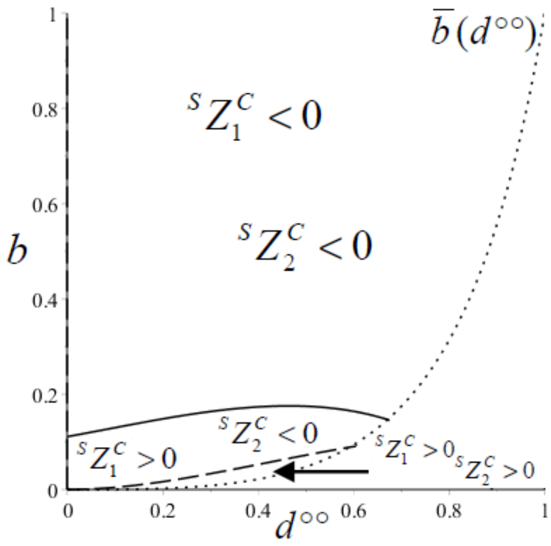

Figure 4. [S – Cournot]. Likelihood of (I,I), $d^{\circ} = 0$.

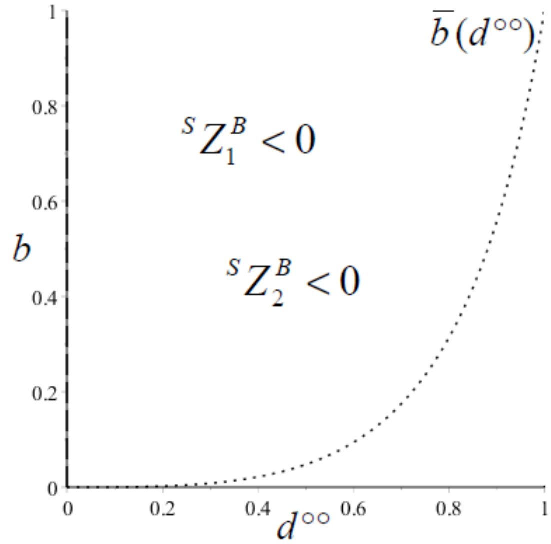

Figure 5. [S – Bertrand]. Likelihood of (I,I), $d^{\circ} = 0$.

Proposition 3. [S versus J]. Cournot. The likelihood of (I,I) in a two-tier industry under mode S is larger than under mode J.

Proof. As ${}^{S,J}Z_1^C := {}^{S}F_1^C - {}^{J}F_1^C > 0$, ${}^{S,J}Z_2^C := {}^{S}F_2^C - {}^{J}F_2^C > 0$ for any $b > \bar{b}(d^{\circ\circ})$ and d°. **Q.E.D.**

Result 2. [S versus J]. Bertrand. The likelihood of (I,I) in a two-tier industry under mode S is smaller than under mode J.

In this case we have that, for any $b > \bar{b}(d^{\circ\circ})$, ${}^{S,J}Z_1^B := {}^{S}F_1^B - {}^{J}F_1^B < 0$ and ${}^{S,J}Z_2^B := {}^{S}F_2^B - {}^{J}F_2^B < 0$ (resp. ${}^{S,J}Z_1^B < 0$ and ${}^{S,J}Z_2^B > 0$) when d° is sufficiently small (resp. large). Notwithstanding the non-univocal result of the comparison between threshold curves, Example 1 and Figure 6 show that even when $d^{\circ} = 0$

area III under mode S (${}^{S}A^{B}_{III}$) is smaller that area III under mode J (${}^{J}A^{B}_{III}$) in a Bertrand setting.

Example 1. To evaluate the likelihood of (I,I) in $(d^{\circ\circ},F)$ space ($d^{\circ}=0$, $b=0.5$), we compute area III under S and J as follows:

$$ {}^{S}A^{B}_{III} := \int_{0}^{0.3101} ({}^{S}F^{B}_{2}+F)dd^{\circ\circ} + \int_{0.3101}^{1} ({}^{S}F^{B}_{1}+F)dd^{\circ\circ} = 0.00519+0.00788=0.01308, $$

and

$$ {}^{J}A^{B}_{III} := \int_{0}^{0.3333} ({}^{J}F^{B}_{2}+F)dd^{\circ\circ} + \int_{0.3333}^{1} ({}^{J}F^{B}_{1}+F)dd^{\circ\circ} = 0.0057+0.00901=0.01472. $$

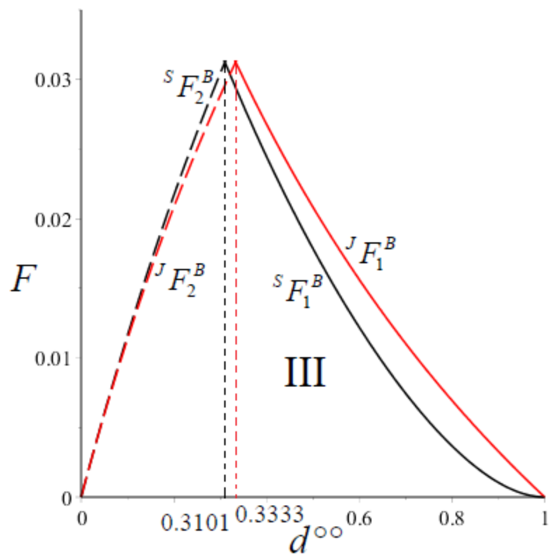

Figure 6. [S versus J – Bertrand]. Area III: S (black) versus J (red) in $(d^{\circ\circ},F)$ space ($d^{\circ}=0$, $b=0.5$).

3. Conclusions

This article analysed the likelihood of R&D investment in product innovation in a two-tier vertical industry (where an upstream supplier and two downstream firms bargain over the terms of a two-part tariff contract). Results are compared with the main findings of a standard one-tier industry, and. The cases of public observable bargaining involving both downstream firms jointly and secret and separate bargaining with each downstream firm are contrasted between them.

Amongst other things, it is shown that is not always true that downstream firms are scarcely incentivised to differentiate products because of a part of the increased rent due to differentiation can be extracted by the monopolistic supplier. In fact, under mode S with quantity-setting firms, the likelihood of (I,I) may be larger than in a one-tier market.

Conflict of Interest The authors declare that they have no conflict of interest.

References

Alipranti, M., Milliou, C., and Petrakis, E., 2014. Price vs. quantity competition in a vertically related market. Economics Letters 124, 122–126.

Basak, D., Wang, L., 2016. Endogenous choice of price or quantity contract and the implications of two-part tariff in a vertical structure. Economics Letters 138, 53–56.

Bernhofen, D.M., Bernhofen, L.T., 1999. On the likelihood of a prisoners' dilemma in a differentiated duopoly. Economics Letters 64, 291–294.

Fanti, L., Gori, L., 2016. A product innovation game with managerial delegation. Mimeo.

Grout, P.A., 1984. Investment and wages in the absence of binding contracts: a Nash bargaining approach. Econometrica 52, 449–460.

Hart, O., Tirole, J., 1990. Vertical integration and market foreclosure. Brookings Papers on Economic Activity: Microeconomics, 205–276.

Horn, H., Wolinsky, A., 1988. Bilateral monopolies and incentives for merger. RAND Journal of Economics 19, 408–419.

Lambertini, L., Rossini, G., 1998. Product homogeneity as a prisoner's dilemma in a duopoly with R&D. Economics Letters 58, 297–301.

Lin, P., Saggi, K., 2002. Product differentiation, process R&D, and the nature of market competition. European Economic Review 46, 201–211.

Milliou, C., Petrakis, E., 2007. Upstream horizontal mergers, vertical contracts, and bargaining. International Journal of Industrial Organization 25, 963–987.

Scherer, F., Ross, D., 1990. Industrial Market Structure and Economic Performance. Houghton Mifflin.

Villas-Boas, S.B., 2007. Vertical relationships between manufacturers and retailers: inference with limited data. Review of Economic Studies 74, 625–652.