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Licensing under vertical product differentiation: Price vs. quantity competition ☆

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ABSTRACT

This paper develops a duopoly model of vertical product differentiation where two domestic firms incur variable costs of quality development. These domestic firms can purchase a superior foreign technology through licensing. Outcomes between Bertrand and Cournot competition are compared. We find that licensing raises domestic welfare, and domestic welfare is higher in Bertrand than in Cournot competition regardless of whether or not domestic firms engage in licensing. Non-exclusive licensing is also found to benefit the domestic country more than exclusive licensing.

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1. Introduction

This paper develops a duopoly model of vertical product differentiation where two domestic competing firms incur variable costs of quality development. Following Motta (1993), we interpret these variable costs of quality development as investment in expensive inputs such as human capital. The domestic firms can purchase an advanced technology, possessed by a multinational firm, by engaging in an international licensing arrangement. Our focus is on the case of exclusive licensing, in which the multinational firm offers a licensing contract exclusively to one domestic firm. Outcomes are compared between price competition (Bertrand) and quantity competition (Cournot). The central research question which the paper seeks to address is as follows: When licensing takes place, how does the nature of competition (Bertrand and Cournot) affect the degree of product differentiation, the licensing fee, domestic firms' profitability, and domestic welfare?

We find that domestic firms differentiate their products more vigorously under Bertrand than under Cournot competition in both cases: with and without licensing. The intuition is that in Bertrand competition, firms tend to separate from their rival when choosing their product quality as doing so gives them larger advantages in setting prices. In the absence of licensing, such a "harsher competition" leads to larger domestic welfare in Bertrand than in Cournot competition. When licensing takes place, we find that the multinational firm can charge a higher licensing fee to the domestic licensee firm in Bertrand than in Cournot competition. However, domestic welfare remains larger in Bertrand than in Cournot competition. Finally, non-exclusive licensing benefits the domestic country more than exclusive licensing from a welfare standpoint.

Our results, as summarized above, are consistent with real world observations. Specifically, in many industries where products sold by the firms are highly substitutable (i.e. not very different in quality), Cournot competition rather than Bertrand competition is often observed. For instance, Reisinger and Ressner (2009) demonstrate that in the audiotapes and disks industry in the U.S., as the goods are highly substitutable, firms usually write quantity contracts with their customers. On the other hand, Bertrand competition is observed in industries where products are highly differentiated, such as the case when quality improvement is costly. Take the motorbike industry as an example. In China, there is a big gap in price (and quality) between Japanese made motorbikes and Chinese made motorbikes.[1] Similarly, in the U.S. automobile industry, Gatesman (2005) shows that mean prices of different standard car models fell between $11,593 and $20,151, with performance rating in the range of [40.0, 53.7]. He also finds a strong relationship between the quality and price, where Japanese cars are

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[1] Source: http://www.businessweek.com/globalbiz/content/jul2006/gb20060717_673201.htm.

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rated as high-quality ones so that their prices are higher compared to U.S. manufactured cars.

We have used the World Bank's Enterprises Surveys (WES) data for India in 2005 to analyze the performance of firms that used foreign technologies and those that did not in the auto components industry. We found that Indian firms using foreign technologies in the auto components industry performed much better than the firms that used domestic technologies. On average, mean profit and mean profit per worker of firms using domestic technologies were equal to 13.87% and 24.88% of those who used foreign technologies, respectively.[2]

Concerning our welfare results, government's support to induce domestic firms to purchase foreign technologies is popular, especially in the industries of developing countries where investment in expensive inputs is required. In the case of the Chinese automobile industry, the government has asked domestic firms to upgrade their technological capabilities by using foreign technologies. Specifically, Gallagher (2003) documents that since the 1970s, the Chinese government has asked Japanese for help in the production of trucks in China. Following this move, Chinese automaker Chang An licensed technology from Suzuki in 1983 to produce its own mini car, and Tianjin Automotive Industry Corporation, another Chinese automaker, licensed technology from Daihatsu in 1986 to produce the mini-sedan Charade. In 1987, the Chinese government established the National Automotive Industry Federation with an aim to assist local automakers to absorb the imported technologies (Vause, 1988).

In the 2000s, a new trend has appeared in the Chinese automobile industry: Chinese automakers purchased a stake in foreign automakers. For example, McGrath (2010) reports that in 2009, Beijing Automotive Industry Holding reached an agreement to acquire certain assets of General Motors' Saab unit. Similarly, in 2010, Geely, another Chinese automaker, purchased Ford's Volvo unit in Sweden. According to many analysts, the purchase of a stake in foreign automakers is a quick way for Chinese automakers to get access to modern technology to produce cars with greater quality. Since Geely purchased Volvo, for instance, the Chinese firm will now have access to the crash test facility of Volvo and, hence, it will be able to improve its car quality (Corkery, 2009).

The above examples suggest that licensing in vertical markets has become an important trend especially in developing countries. At the same time, the government of these developing countries often encourages licensing as they anticipate the long-term benefit of the technological development in the domestic industries. However, very little has been known in the literature regarding the welfare benefits that different modes of competition (Bertrand and Cournot) could bring about to the developing countries in this context. This motivates the present study.

It should be noted that Li and Song (2009), Li and Wang (2010), Nabin et al. (2013), and Nguyen et al. (2013) have similar analysis on international technology licensing using vertical product differentiation models. However, these papers assume away the variable costs of quality development so that they do not address the situation in which firms invest in expensive inputs (such as human capital). Furthermore, Li and Song (2009) and Li and Wang (2010) assume exogenous quality; thus, the strategic quality choice is absent in their analysis.

Meanwhile, a number of papers have discussed variable costs of quality development, but in models without technology licensing (Das and Donnenfeld, 1987, 1989; Johnson and Myatt, 2003; Motta, 1993; Mussa and Rosen, 1978). These papers also focus on the case of symmetric firms. In practice, competing firms invest differently in human capital, especially in the case where some firms seek international technology licensing to improve their product quality, while some other firms undertake their own investment to improve their product quality. Competition in this context is, therefore, between asymmetric firms: the firms that use superior foreign technologies and the firms that use obsolete local technologies.

By focusing on variable costs of quality development, this paper fills in the gap in the literature by examining the impact of international technology licensing on the choices of quality by the domestic firms and their impact on welfare. The rest of the paper will proceed as follows. Section 2 presents a simple duopoly model of vertical product differentiation with international technology licensing, in which the domestic firms incur variable costs of quality development. Sections 3 and 4 examine the Bertrand and Cournot outcomes, respectively, followed by a comparison of results between Bertrand and Cournot competition in Section 5. Section 6 discusses exclusive licensing and non-exclusive licensing. Section 7 offers some concluding remarks.

2. The model

Two domestic firms, denoted by firm 1 and firm 2, compete by producing differentiated products in the domestic market. Without loss of generality, we assume that firm 1 is the producer of the high-quality product and firm 2 is the producer of the low-quality product. Each firm i incurs a marginal variable cost of the form $c_i = q_i^2/2$, where q_i (≤ 1) is the level of quality it chooses. These variable costs can be interpreted as investment in human capital (Motta, 1993). There is a multinational firm who possesses a superior technology and can licence the technology exclusively to one of the domestic firms.[3] By purchasing the superior technology from the multinational firm, the domestic firm incurs a licensing fee and it can choose the maximum level of quality without incurring the quality development costs. For tractability, assume that the licensing fee, F, is a lump-sum payment (fixed-fee licensing) set by the multinational firm on a take-it-or-leave-it basis, and that with exclusive licensing, firm 1 is the domestic firm that engages in the licensing arrangement.[4]

Consider the following four-stage game. In the first stage, the multinational firm announces its offer of technology licensing to firm 1 and the licensing fee, F, on a take-it-or-leave-it basis. In the second stage, firm 1 chooses whether to engage in the licensing arrangement with the multinational firm. Observing firm 1's decision in the second stage, in the third stage, firms 1 and 2 simultaneously choose the quality level for their product (where if licensing takes place in stage 1 then the quality level set by firm 1 is $q_1 = 1$). In the last stage, they compete in either prices (Bertrand) or quantities (Cournot).[5]

Consumers are indexed by a taste parameter v, which is uniformly distributed between 0 and 1. We assume that each consumer can buy at most one unit of the product. The indirect utility for the consumer j, indexed by v_j, who purchases the product of quality q_i at the price p_i, is given by $U_j = v_j q_i - p_i$, and it is zero if she does not buy any product.

The game described above has two stage-3 subgames. One is where there is no licensing arrangement in stage 2 between firm 1 and the

[2] There is no information on exclusive or non-exclusive licensing in the WES data. However, given the nature of vertical differentiation in the auto components industries, it is expected that non-exclusive licensing where licensee firms produce products of same quality is not likely the case. Whether technology licensing is the sole factor driving the result is left for future research, since doing so requires an econometric assessment which falls outside the scope of the present paper.

[3] In Section 6, we consider non-exclusive licensing where the multinational firm can license its technology to both domestic firms.

[4] Dhar and Joseph (2012), in their survey of literature and evidence on North–South technology licensing, report that in reality, the owners of patented technologies (Northern firms) are often inclined to enter into licensing agreements only if the recipients (Southern firms) have adequate domestic capabilities to assimilate the technologies. Li and Wang (2010) also present several evidences suggesting that exclusive licensing is a popular licensing scheme used in practice. Hence, our assumption that the multinational firm offers the licensing contract to firm 1 (the high-quality firm) in the case of exclusive licensing is consistent with reality.

[5] Hence, there will be two different scenarios concerning the quality choice by the domestic firms. The first scenario is one in which both firms simultaneously and non-cooperatively choose their product quality, and incur a variable cost (which is convex in quality). The second is one in which firm 1's quality is fixed, and importantly, its cost of quality structure changes from a variable to a fixed cost (in the form of a licensing fee). Firm 2 is the only firm that chooses product quality in this second scenario.

multinational firm, and one is where there is a licensing arrangement in stage 2. The game is solved using backward induction.

3. Bertrand competition

In this section we derive the equilibrium solutions for the case in which firms 1 and 2 choose their product qualities simultaneously in the third stage and then compete in prices in the last stage of the game. Consider first the subgame in which firm 1 chooses not to engage in the licensing arrangement with the multinational firm. The consumer who is indifferent between buying the product of quality q_1 (high-quality) and q_2 (low-quality) has the taste parameter v_1 satisfying $v_1 = (p_1 - p_2)/(q_1 - q_2)$, and the consumer who is indifferent between buying the product of quality q_2 and not buying at all has the taste parameter v_2 satisfying $v_2 = p_2 / q_2$.[6] Demands for firm 1 and firm 2 are respectively given by:

$$d_1 = 1 - v_1 = 1 - (p_1 - p_2)/(q_1 - q_2), \tag{1}$$

$$d_2 = v_1 - v_2 = (p_1 - p_2)/(q_1 - q_2) - p_2/q_2. \tag{2}$$

These demands yield the following profits in the last stage for firms 1 and 2, respectively:

$$\pi_1 = (1 - (p_1 - p_2)/(q_1 - q_2))\left(p_1 - q_1^2/2\right), \tag{3}$$

$$\pi_2 = ((p_1 - p_2)/(q_1 - q_2) - p_2/q_2)\left(p_2 - q_2^2/2\right). \tag{4}$$

The first order conditions yield the following equilibrium prices:

$$p_1 = q_1\left(2q_1^2 + 4q_1 - 4q_2 + q_2^2\right)/(8q_1 - 2q_2), \tag{5}$$

$$p_2 = q_2\left(q_1^2 + 2q_1 - 2q_2 + 2q_1q_2\right)/(8q_1 - 2q_2). \tag{6}$$

By substituting these equilibrium prices in Eqs. (3) and (4) and solve for optimal qualities, we arrive at the following first order conditions in stage 3:

$$24q_1^3 - 22q_1^2q_2 + 5q_1q_2^2 + 2q_2^3 - 16q_1^2 + 12q_1q_2 - 8q_2^2 = 0, \tag{7}$$

$$4q_1^3 - 19q_1^2q_2 + 17q_1q_2^2 - 2q_2^3 + 8q_1^2 - 14q_1q_2 = 0. \tag{8}$$

The unique solutions are $q_1 = 0.8195$ and $q_2 = 0.3987$. With these results, it follows that equilibrium profits for firms 1 and 2 are respectively $\pi_1 = 0.0328$ and $\pi_2 = 0.0243$.

Consider next the subgame in which firm 1 chooses to engage in the licensing arrangement with the multinational firm. Its product quality is the maximum level, $q_1 = 1$.[7] Thus, in the quality setting stage, only firm 2 chooses its optimal quality. Stage-4 profits for the firms are:

$$\pi_1 = (1 - (p_1 - p_2)/(1 - q_2))p_1 - F, \tag{9}$$

$$\pi_2 = ((p_1 - p_2)/(1 - q_2) - p_2/q_2)\left(p_2 - q_2^2/2\right). \tag{10}$$

First order conditions yield equilibrium prices:

$$p_1 = \left(4 - 4q_2 + q_2^2\right)/(8 - 2q_2), \tag{11}$$

$$p_2 = q_2/(4 - q_2). \tag{12}$$

By substituting these equilibrium prices in Eq. (10), the first order condition in stage 3 for firm 2 is:

$$2q_2^4 - 19q_2^3 + 52q_2^2 - 46q_2 + 8 = 0. \tag{13}$$

We find that $q_1 = 0.2278$ is the unique solution. The equilibrium profits for firm 1 and firm 2 are respectively $\pi_1 = 0.2244 - F$ and $\pi_2 = 0.0067$. The result in which firm 2 lowers its product quality when firm 1 undertakes licensing suggests that the qualities are strategic substitutes rather than strategic complements in our model.[8] Indeed, as firm 1 engages in licensing and chooses the maximum possible quality, it also lowers the price for its product and hence it serves a larger market segment (see Table 1, where $1 - v_1$ is the segment of the market served by firm 1, and $v_1 - v_2$ is the segment of the market served by firm 2). This in turns leaves firm 2 with the only option of lowering the price for its product, and it serves a smaller market segment comparing to the case of no licensing.

4. Cournot competition

In this section we derive the equilibrium solutions for the case in which firms 1 and 2 choose their product qualities simultaneously in the third stage and then compete in quantities in the last stage of the game. Consider first the subgame in which firm 1 chooses not to engage in the licensing arrangement with the multinational firm. The demands for the firms are still given by Eqs. (1) and (2). We can invert the system of demand functions:

$$p_1 = q_1 - d_1q_1 - d_2q_2, \tag{14}$$

$$p_2 = (1 - d_1 - d_2)q_2. \tag{15}$$

These yield the following profits:

$$\pi_1 = d_1\left(q_1 - d_1q_1 - d_2q_2 - q_1^2/2\right), \tag{16}$$

$$\pi_2 = d_2\left((1 - d_1 - d_2)q_2 - q_2^2/2\right). \tag{17}$$

The first order conditions yield the solutions:

$$d_1 = \left(-2q_1^2 + q_2^2 + 4q_1 - 2q_2\right)/(8q_1 - 2q_2), \tag{18}$$

$$d_2 = \left(q_1^2 - 2q_1q_2 + 2q_1\right)/(8q_1 - 2q_2). \tag{19}$$

[6] Interested readers should read Das and Donnenfeld (1987, 1989), Aoki and Prusa (1997), Johnson and Myatt (2003), Boccard and Wauthy (2005), and Toshimitsu (2005) for the derivation of these equations.

[7] We assume that firm 1's quality is maximum ($q_1 = 1$) for convenience (Boccard and Wauthy (2005) solve a similar game without licensing and firms' costs of quality development are zero. They find that the high-quality firm chooses the maximum quality which is equal to 1, while the low-quality firm chooses the quality which is equal to 4/7). The qualitative nature of most of our results would remain unchanged should this maximum quality be in the range of [0.82, 1]. Indeed, we have undertaken the similar analysis for the case licensing allows firm 1 to choose the maximum quality $q_1 = 0.9$. Comparing licensing outcomes in Bertrand and Cournot competition with the case firm 1 chooses $q_1 = 1$, we find that firm 2 slightly lowers its quality under Bertrand competition and that it slightly raises its quality under Cournot competition. However, all implications remain exactly the same as those presented in Sections 3–5. Details are available from the authors upon request.

[8] We thank a referee for suggesting this point.

Table 1
Welfare for the domestic country.

Variable	No licensing, Bertrand	No licensing, Cournot	Licensing, Bertrand	Licensing, Cournot
q_1	0.8195	0.7381	1.0000	1.0000
q_2	0.3987	0.5856	0.2278	0.3765
p_1	0.4533	0.4337	0.4163	0.4676
p_2	0.1512	0.3145	0.0604	0.1537
v_1	0.7179	0.7816	0.4609	0.5323
v_2	0.3792	0.5371	0.2651	0.3604
CS	0.0936	0.0664	0.1737	0.1452
$\pi_1 max$	0.0328	0.0353	0.2244	0.2187
$\pi_1 min$	0.0328	0.0353	0.0328	0.0353
π_2	0.0243	0.0350	0.0067	0.0115
$Wmax$	0.1507	0.1367	0.4048	0.3754
$Wmin$	0.1507	0.1367	0.2132	0.1920
$Fmax$			0.1916	0.1834

Notes: $\pi_1 max$, $\pi_1 min$, $Wmax$ and $Wmin$ are firm 1's profit when the licensing fee is zero, firm 1's profit when the licensing fee is set at maximum, welfare for the domestic country when the licensing fee is zero and welfare for the domestic country when the licensing fee is set at maximum, respectively. The maximum licensing fee, $Fmax$, is the value of F such that firm 1 is indifferent between undertaking licensing and no licensing.

Using these results, the first order conditions in stage 3 (firms choosing optimal qualities) are:

$$24q_1^3 - 10q_1^2 q_2 + 4q_1 q_2^2 + q_2^3 - 16q_1^2 + 4q_1 q_2 - 2q_2^2 = 0, \tag{20}$$

$$4q_1^2 - 23q_1 q_2 + 2q_2^2 + 8q_1 + 2q_2 = 0. \tag{21}$$

Hence, $q_1 = 0.7381$ and $q_2 = 0.5856$. The profits for the firms are $\pi_1 = 0.0353$ and $\pi_2 = 0.035$.

Consider next the subgame in which firm 1 chooses to engage in the licensing arrangement with the multinational firm. Its product quality is the maximum level, $q_1 = 1$. Thus, in the quality setting stage, only firm 2 chooses its optimal quality by anticipating the licensing arrangement between firm 1 and the multinational firm. Stage-4 profits for the firms are:

$$\pi_1 = d_1(1 - d_1 - d_2 q_2) - F, \tag{22}$$

$$\pi_2 = d_2\left((1 - d_1 - d_2)q_2 - q_2^2/2\right). \tag{23}$$

We find that equilibrium quantities are given by:

$$d_1 = \left(4 - 2q_2 + q_2^2\right)/(8 - 2q_2), \tag{24}$$

$$d_2 = (1 - q_2)/(4 - q_2). \tag{25}$$

By substituting these equilibrium quantities in Eq. (23), the first order condition in stage 3 for firm 2 is:

$$q_2^2 - 11q_2 + 4 = 0. \tag{26}$$

We find that $q_2 = 0.3765$ is the unique solution. Equilibrium profits for firm 1 and firm 2 are respectively $\pi_1 = 0.2187$ and $\pi_2 = 0.0115$. As firm 2 lowers the quality of its product, qualities are also strategic substitutes rather than strategic complements in this case. The driving force of this result lies in the choice of quantity: with an advantage of choosing the maximum possible product quality under licensing, firm 1 also raises the quantity level for its product in equilibrium. Such a tougher competition leads firm 2 to choose both a smaller quantity and a smaller quality level comparing to the case of no licensing (see Table 1).

5. Bertrand vs. Cournot competition

In this section, we compare outcomes under price competition and under quantity competition. Notice first that welfare for the domestic country consists of firm 1's and firm 2's profit and consumer surplus. Given the set-up, consumer surplus is:

$$CS = \int_{v_1}^{1} (vq_1 - p_1)dv + \int_{v_2}^{v_1} (vq_2 - p_2)dv. \tag{27}$$

Using the results from the previous sections and let W denote welfare for the domestic country, where $W = \pi_1 + \pi_2 + CS$, we arrive at Table 1, which shows the equilibrium levels of profit and welfare.[9]

Lemma 1. *The degree of product differentiation under Bertrand competition is always greater than that under Cournot competition.*

Proof. From Table 1, it follows that when there is no licensing, the gap of quality chosen by firms 1 and 2 is $\Delta q_b = 0.8195 - 0.3987 = 0.4208$ in Bertrand and $\Delta q_c = 0.7381 - 0.5856 = 0.1525$ in Cournot competition. With licensing, the quality gap in the case of Bertrand competition is $\Delta q_{lb} = 1 - 0.2278 = 0.7722$, and in the case of Cournot competition, it is $\Delta q_{lc} = 1 - 0.3765 = 0.6235$.

Lemma 1 tells us that domestic firms compete more fiercely in the quality setting stage if they set prices in the subsequent stage than if they set quantities. As a result, the quality gap is larger under Bertrand than under Cournot competition. In other words, firms tend to separate from each other under Bertrand competition. The interior solutions arise because of two reasons: (i) there are quality development costs, so that the high-quality firm should not choose too high a quality as its revenue might not be great enough to cover costs, and (ii) there is a subsequent pricing competition, so that the low-quality firm should not choose too low a quality as it has to lower the price. Under Cournot competition, the firms tend to choose quality levels close to each other in the third stage, which provides a greater room for them to set a large quantity level in the subsequent stage. This finding is consistent with Motta (1993) for the case of no licensing.

Proposition 1. *The following hold in equilibrium:*

- **(i)** *In the absence of licensing, the domestic country's government strictly prefers Bertrand to Cournot competition.*
- **(ii)** *When licensing takes place, both the multinational firm and the domestic country's government strictly prefer Bertrand to Cournot competition.*

Proof. The proof of (i) follows from Table 1. To show (ii), note that the maximum licensing fee is one in which firm 1 is indifferent between licensing and no licensing. Thus, it is $F_b = 0.2244 - 0.0328 = 0.1916$ under Bertrand competition, and $F_c = 0.2187 - 0.0353 = 0.1834$ under Cournot competition. Similarly, welfare for the domestic country is given by the sum of firm 1's profit, firm 2's profit and consumer surplus. Suppose the multinational firm is able to set the maximum licensing fee in all cases, then, by Table 1, welfare for the domestic

[9] Indeed, with the assumption of a take-it-or-leave-it offer of the licensing contract by the multinational firm to firm 1, the licensing fee can be set at the maximum level by the multinational firm. However, in reality, in some cases the domestic country can influence the licensing fee and thus the multinational firm might not be able to extract the maximum fee. In an extreme case, the licensing fee is zero (or very close to zero). This extreme case is also reported in Table 1.

country is higher in Bertrand competition than in Cournot competition in all cases.

The welfare implication of Proposition 1 for the case of no licensing is discussed in Motta (1993).[10] In the case of licensing, fiercer competition from the quality setting stage induces competing firms to differentiate their products more vigorously under Bertrand than under Cournot competition, and this enables the high-quality firm to make larger profit. Hence, through the licensing arrangement, the multinational firm can extract larger consumer rents in Bertrand than in Cournot competition. At the same time, licensing leads to an outcome in which the firms serve a larger market segment with Bertrand than with Cournot competition (lower value of v_2) which benefits consumers. This in turn makes Bertrand competition more attractive for the domestic country from the welfare standpoint. Specifically, in Bertrand competition, about 73.5% of the market is served when licensing between firm 1 and the multinational firm takes place (comparing to 64% in Cournot competition with licensing).

Proposition 2. *Licensing between firm 1 and the multinational firm raises domestic welfare in both Bertrand and Cournot competition.*

Proof. Suppose that the multinational firm sets the maximum possible licensing fee so that firm 1 is indifferent between licensing and no licensing. Then, from Table 1, the increase in consumer surplus exceeds the reduction in firm 2's profit due to licensing in all cases. Hence, licensing raises welfare for the domestic country.

The result of Proposition 2 is consistent with the finding of Nabin et al. (2013) and Nguyen et al. (2013) where they consider licensing with fixed costs of quality development. The result implies that although licensing between firm 1 and the multinational firm exerts a negative impact on firm 2, the extra rents that domestic consumers receive as a result of firm 1's choosing a higher quality level, and consequently a larger market coverage, are dominating the changes in domestic welfare.

Proposition 2 is also a generalization of the results in Li and Wang (2010), where these authors consider a model with exogenous quality and without quality development costs. As discussed above, quality competition in the third stage is the main driving force of our results, since larger product differentiation (i.e. firms choosing more distant quality levels) leads to larger market coverage. This is in addition to the impact of quantity competition that is discussed in Li and Wang's paper.

6. Exclusive vs. non-exclusive licensing

In this section we extend the benchmark model to study the case of non-exclusive licensing, where the multinational firm can offer the licensing arrangement to both domestic firms. To focus the analysis, we assume that the multinational firm offers the same take-it-or-leave-it deal to both domestic firms so that the total maximum licensing fee it can collect is given by $2f$, where f is the maximum licensing fee it collects from one of the domestic firms. This alters the first two stages of the game described in Section 2.

In the case of Bertrand competition, it is straightforward to show that non-exclusive licensing can never be an outcome of the entire game. In fact, under price competition, if both firms choose the same level of product quality (equal to the maximum level, $q = 1$) then in equilibrium, they undercut prices and thus get a zero profit. On the other hand, if the firms are free to choose any quality level in the range [0, 1] then the analysis of Boccard and Wauthy (2005) with zero cost of quality development suggests that in equilibrium, one firm chooses the maximum possible quality (that is equal to 1) and the other firm chooses the level of quality equal to 4/7. Their profits are 0.146 for the firm that chooses the maximum quality, and 0.021 for the other firm. It is apparent that the firm that chooses quality equal to 4/7 has a profit, which is lower compared to firm 2's equilibrium profit without licensing (see Table 1), so that it does not have an incentive to engage in the licensing agreement.

Table 2
Payoffs under non-exclusive licensing with Cournot competition.

		Firm 2	
		Licensing	No licensing
Firm 1	Licensing	$0.0353+\epsilon$, $0.0353+\epsilon$	$0.0353+\epsilon$, 0.0115
	No licensing	0.0115, $0.0353+\epsilon$	0.0353, 0.035

Notes: ϵ is a small amount transferred from the multinational firm to the domestic firm(s) that participates in the licensing arrangement to give the domestic firm(s) an incentive to undertake licensing.

In the case of Cournot competition, with unique quality level ($q_1 = q_2 = 1$), the firms compete in quantities in stage 4. The analysis will be similar to those of Li and Wang (2010) where each firm chooses $d_1 = d_2 = 1/3$ and each obtains a profit $\pi_1 = \pi_2 = \frac{1}{9} - f$. Comparing to no licensing, the value of f must be such that both firms have incentive to undertake licensing, so that f is not greater than $\frac{1}{9} - 0.0353 = 0.0758$. Hence, the total maximum licensing fee for the multinational firm is $2f = 0.1516$. Table 2 below shows the payoff matrix in which (Licensing, Licensing) is indeed the subgame perfect Nash equilibrium outcome under non-exclusive licensing.[11]

Although (Licensing, Licensing) appears to be the subgame perfect Nash equilibrium outcome under non-exclusive licensing, Proposition 3 below tells us that in case where the multinational firm has the option between exclusive licensing and non-exclusive licensing, it would choose exclusive licensing to maximize its profit. However, for the domestic country, it is optimal to allow only non-exclusive licensing.

Proposition 3. *The domestic country's government strictly prefers non-exclusive licensing to exclusive licensing, and the multinational firm strictly prefers exclusive licensing to non-exclusive licensing under Cournot competition.*

Proof. With Cournot competition, the maximum licensing fee under exclusive licensing is $F_c = 0.1834$ (by Table 1), which is larger than $2f = 0.1516$, the licensing fees that the multinational firm can collect under non-exclusive licensing. Under non-exclusive licensing, we also have that equilibrium prices are $p_1 = p_2 = 1/3$, and thus the consumer who is indifferent between purchasing a product by either firm 1 or firm 2 has the taste value $v = 1/3$. Hence, consumer surplus is $CS = \int_{1/3}^{1} (v - 1/3)dv = 0.2778$, and domestic welfare is $W = 0.0353 + 0.0353 + 0.2778 = 0.3484$, which is larger than domestic welfare under exclusive licensing with Cournot competition (by Table 1).

The findings of Proposition 3 imply that under vertical product differentiation with variable costs of quality development, supporting domestic firms to engage in international technology licensing is welfare

[10] Li and Ji (2010) compare Bertrand and Cournot outcomes in a horizontal product differentiation model with licensing and find that Cournot competition is better for the society. However, their focus is on R&D while our focus is on strategic qualities. At the same time, licensing occurs between two domestic firms in their model, while it is assumed to happen between a multinational firm and one domestic firm (or both domestic firms) in our model.

[11] Consider the case when both firms are free to choose any quality level in the range [0, 1]. We find that the stage-3 equilibrium profits for the firms are $\pi_1 = \frac{q_1(2q_1 - q_2)^2}{(4q_1 - q_2)^2} - F$ (for firm 1, which chooses high quality) and $\pi_2 = \frac{q_2^2 q_2}{(4q_1 - q_2)^2} - F$ (for firm 2, which chooses low quality). It can be verified that $\frac{\partial \pi_1}{\partial q_1} > 0$, and $\frac{\partial \pi_2}{\partial q_2} > 0$, which imply that each firm choosing the maximum quality level is the unique equilibrium outcome in case they both engage in licensing.

enhancing. However, since non-exclusive benefits domestic welfare more than exclusive licensing (mainly due to a large improvement in consumer surplus), the domestic country should only allow non-exclusive licensing.[12]

7. Conclusion

What are the impacts of international technology licensing on the degree of product differentiation, domestic firms' profitability and welfare? In this paper, we consider a model where domestic firms face variable costs of quality development and show that the firms compete more fiercely under Bertrand than under Cournot competition. This holds regardless of whether or not one of the domestic firms undertakes international technology licensing. We also show licensing raises domestic welfare regardless of the nature of competition, and both the multinational firm and the domestic country's government prefer Bertrand to Cournot competition when licensing takes place. Finally, welfare for the domestic country is higher with non-exclusive licensing than with exclusive licensing.

Would these results hold under a horizontal product differentiation model? In Appendix A, we consider an alternative set-up in which the products of the domestic firms are horizontally differentiated, in a similar fashion to that of Hackner (2000) and Symeonidis (2003). We find, within certain parameter ranges, the domestic firms choose the same level of product quality under both Cournot and Bertrand competition, even in the presence of licensing. Licensing could hurt domestic welfare in the case of Bertrand competition in this case. Furthermore, the domestic country strictly prefers Bertrand to Cournot competition, while the multinational firm strictly prefers Cournot to Bertrand competition.[13] Therefore, vertical differentiation and horizontal differentiation could lead to qualitatively different results and policy implications.

The findings of this paper complement the growing literature on the topic of international technology licensing using vertical product differentiation models. The analysis also helps to justify the strategy toward supporting domestic firms to participate in international technology licensing arrangements to improve technological capabilities by many governments around the world, especially in the case where domestic investment in technology is expensive (see Section 1).

Our analysis has been made tractable by making standard assumptions, especially the (uniform) distribution of the taste parameter and the specific cost function (Motta, 1993). However, most of our results would remain unchanged if these assumptions were relaxed to a certain degree. For instance, the results would hold if we retain the quasi-convex cost function of quality and the uniform distribution but change the value of the highest valuation parameter, or change the coefficient of the quasi-convex cost function (which is equal to 1/2 in our analysis). Unfortunately the cases of royalty licensing and two-part tariff become non-tractable with the current framework, which are left for future research.

Appendix A

In this appendix, we consider a duopoly with similar characteristics (including notations and stages of the game) as the one presented in Section 2, except for differences in the demand structure. Following Hackner (2000) and Symeonidis (2003), assume that there are S identical consumers and that the utility function of each consumer takes the form:

$$U = d_1 q_1 + d_2 q_2 - d_1^2 - d_2^2 - \sigma d_1 d_2 + M, \tag{A.1}$$

where M denotes the expenditure on outside goods, and σ ($\in[0, 2]$) denotes the degree of horizontal product differentiation. To see if similar results as those presented in Sections 3–5 could arise in the equilibrium of the game in this case, we assume that $\sigma = 1$ in what follows. The inverse demand function of each consumer for product of quality q_i is given by:

$$p_i = q_i - 2d_i - d_j, \tag{A.2}$$

and the demand function is:

$$d_i = \frac{2(q_i - p_i) - \left(q_j - p_j\right)}{3}, \tag{A.3}$$

where $i \neq j$ and $i,j \in \{1, 2\}$. Let us first consider Bertrand competition. In the absence of licensing, stage-4 profit for firm i is:

$$\pi_i = S\frac{2(q_i - p) - \left(q_j - p_j\right)}{3}\left(p_i - \frac{q_i^2}{2}\right). \tag{A.4}$$

The first order condition yields a symmetric equilibrium price $p_i = \frac{q_i + q_i^2}{3}$. Using this result and solving for optimal quality q_i in stage 3, we find that firm i chooses, $q_i = 1$, and hence $\pi_i = S / 54$. Consumer surplus and domestic welfare are respectively given by $CS = 2\left(\int_0^{d_i}(p_i)dx - p_i d_i\right) = 2S/27$, and $W = 3S/27$.

When licensing takes place under Bertrand competition, firm 1 chooses $q_1 = 1$. In this case, stage-4 profits for firm 1 and firm 2 are respectively given by:

$$\pi_1 = S\frac{2(1 - p_1) - (q_2 - p_2)}{3}p_1 - F, \tag{A.5}$$

$$\pi_2 = S\frac{2(q_2 - p_2) - (1 - p_1)}{3}\left(p_2 - \frac{q_2^2}{2}\right). \tag{A.6}$$

First order conditions lead to equilibrium prices: $p_1 = (7 + q_2^2 - 2q_2)/15$, and $p_2 = (-2 + 4q_2^2 + 7q_2)/15$. Using these results and solving for firm 2's optimal quality in stage 3, we find that firm 2 chooses $q_2 = 1$ in equilibrium. Hence, we have $\pi_1 = 24S / 225 - F$, $\pi_2 = S / 150$, and $CS = 17S / 225$. Assume that the multinational firm sets the maximum licensing fee so that $\pi_1 = S / 54$. These imply that $F = 0.088S$, and $W = 0.101S$.

We next solve the game by considering Cournot competition. In the absence of licensing, stage-4 profit for firm i is same as in Eq. (A.4), and in symmetric equilibrium it chooses quantity $d_i = (q_i - q_i^2)/5$. Using this result, we find that firm i chooses quality $q_i = 1$ in stage 3. Equilibrium profit for each firm, consumer surplus, and domestic welfare are $\pi_1 = \pi_2 = S/50$, $CS = S/50$, and $W = 3S/50$, respectively.

Under Cournot competition with licensing, firm 1 chooses $q_1 = 1$, and stage-4 profits for domestic firms are same as in Eqs. (A.5) and (A.6). Equilibrium quantities are $d_1 = (4 - q_2 + q_2^2/2)/15$ and $d_2 = (4q_2 - 2q_2^2 - 1)/15$. Using these results and solving for firm 2's optimal quality in stage 3, we find that firm 2 chooses $q_2 = 1$ in equilibrium. Hence, profit for firm 1 is $\pi_1 = 98S / 900 - F$. Again, assuming that the multinational sets the maximum licensing fee, we have $\pi_1 = S/50$ and $F = 0.089S$. Then, $\pi_2 = 2S / 225$, $CS = 53S / 900$, and $W = 0.088S$ in equilibrium.

Two remarks follow from the above analysis. First, licensing decreases domestic welfare in Bertrand competition, and it raises domestic welfare

[12] The result might change if, for example, the multinational firm can differentiate the domestic firms and charge them different licensing fee, which is not the case considered in this paper.

[13] We thank a referee for suggesting this robustness check.

in Cournot competition. Second, the domestic country strictly prefers Bertrand to Cournot competition with or without licensing, and the multinational firm strictly prefers Cournot to Bertrand competition. These are in sharp contrast to our main results as presented in Sections 3–5. The driving force for all of these results is the choice of quality by the domestic firm that does not participate in the licensing arrangement. Specifically, it chooses the same quality level as one chosen by the domestic firm that engages in the licensing arrangement. This leads to qualitatively different results and policy implications of vertical product differentiation and horizontal product differentiation.

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