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Tariff induced licensing contracts, consumers' surplus and welfare

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ABSTRACT

We construct a duopolistic trade model with technology transfer and consider two-part tariff licensing contracts. We show that a tariff on foreign products can influence the licensing strategy of the foreign firm. There is a trade-off between a tariff and a royalty license in affecting the product price. We show in particular that a tariff can be chosen so as to induce fee licensing and maximize both consumers' surplus and domestic welfare. This resolves the so-called conflict between these two objectives in respect of the choice of a tariff. The paper provides a number of testable hypothesis.

1. Introduction

Many countries, particularly the developing ones, after following a policy of protectionism for a long time, have switched to the policy of liberalization and opening up. The basic thrust of this liberalization policy is to reduce trade restrictions and promote free competition. The World Trade Organization (WTO), the key international organization in world trade, has been entrusted with the task of framing rules and regulations and implementing a free and smooth movement of goods and services between countries. The WTO is insisting throughout the period on lowering the tariff rates to the minimum. Still many countries, both WTO members and non-members, are observed to continue with high tariffs,[1] and this is happening in spite of an internal pressure to lower tariffs to favor the consumers who were the worst sufferers in the regime of protection and trade restriction. Therefore, it calls for a more careful analysis. Perhaps tariff as an instrument cannot be ignored in the process of development even in a period of liberalization.

Under liberalization as tariffs on foreign products are lowered, the foreign firms find it easy to enter the domestic market. This generally increases competition in the domestic market and benefits the consumers. One may then tend to believe that consumers' welfare would be maximum if tariffs are reduced to zero. A positive tariff, on the other hand, benefits the local firms; the domestic government also collects tariff revenue on foreign products. To the extent consumers suffer under tariff protection, the local government may perhaps justify positive tariffs stating that it seeks to maximize domestic welfare. The existing literature generally accepts this conflict to exist between welfare maximization and loss of consumers' surplus. Hence one purpose of the present paper is to examine whether it is possible to design a tariff policy that will target to maximize both social and consumers' welfare. The related question is: Does a tariff benefit the consumers? A government pursuing a tariff protection generally raises its domestic welfare, but that is often at the cost of a higher product price. So the consumers as a class become adversely affected. To a political party in power seeking to win an election, such a policy may not be desirable. After all, consumers form the largest electorate group; so consumers' welfare cannot be ignored.

One important feature of the present paper is that while analyzing tariff protection, we introduce technology licensing. When a country follows a policy of prohibitive tariff, the foreign firm cannot directly enter the domestic market with goods. Under this situation it transfers its superior technology to a domestic firm and extracts rent from the domestic market by charging an appropriate price for the transferred technology.[2] Under non-prohibitive tariffs, on the other hand, not only can the foreign firm enter the domestic market directly, but at the same time it has the option to transfer its superior technology to its product market competitor. Technology transfer from an advanced foreign firm to a technologically backward domestic firm is common and well-documented. A recent survey conducted by the OECD in collaboration

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[1] This is evident from the statistics and information published in the World Tariff Profiles 2015 (see the website www.wto.org/statistics).

[2] This was actually the experience in India before liberalization (see, for instance, Alam (1985)).

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with the European Patent Office and the University of Tokyo shows that at least one out of four firms in Europe and more than one in every four firms in Japan do license patents to non-affiliated partners (Zuniga and Guellec, 2009). In an empirical study Anand and Khanna (2000) find that licensing of patents is quite high in the industries like chemicals and pharmaceuticals, electrics and electronics, and computer and telecommunications. In fact, licensing is more frequent in the industries where patent protection is more effective (Arora, 1995; Gambardella et al., 2007). Therefore, it is natural to assume that whenever technology transfer is profitable, the firms across borders will get involved in a technology licensing deal.[3]

The basic motivation behind this paper is to examine the relationship between tariffs and licensing contracts. Our question is: How does a tariff affect the licensing strategy of the technology supplier? Kabiraj and Marjit (2003) have constructed a duopolistic trade model showing that a well-directed tariff can induce the foreign firm transfer its superior technology to its rival (and under some situations such a tariff raises consumers' surplus relative to the free trade situation). But they have restricted to the assumption of technology licensing under a fixed fee contract only; hence their paper does not allow the foreign firm choose the licensing contract optimally. In a duopoly setup, with patentee as an insider, a fixed fee contract can occur only if the licensor's technology is close to that of the licensee in terms of the unit cost of production (e.g., Marjit, 1990). This means Kabiraj and Marjit (2003) have considered the possibility of transfer for only a subset of cost-reducing technologies. Moreover, as Wang (1998) has shown, in a duopoly with insider (or producing) patentee, not only transfer of any non-drastic innovation is profitable under the royalty contract to the licensor, but more importantly, the optimal royalty contract strictly dominates the fee contract from the perspective of the patentee.[4] In the present paper we reconcile the ideas underlying Wang (1998) and Kabiraj and Marjit (2003) by allowing the patentee behave optimally. Hence we claim to have proposed a more consistent and enriched model than theirs. It is then interesting to study whether even under this situation a tariff policy be designed so as to induce the foreign firm transfer its superior technology under a fee contract. We construct a similar duopolistic trade model as in Kabiraj and Marjit (2003) (equivalently, it is the Wang (1998) model with one foreign firm and one local firm) with the possibility of technology transfer from the foreign firm to the domestic firm, and study how the licensing strategy can be influenced by the choice of tariff rates. That a tariff can influence the licensing strategy of the foreign patentee is never recognized in the literature.

The empirical literature shows that a licensing contract consists of a fee only or a royalty only, or both upfront fee and royalty. For instance, in a survey of firms Rostoker (1984) has shown that 39 per cent of cases have royalty licensing alone, 13 per cent have fee licensing alone and 46 per cent of cases have both fee and royalty contracts. Kamien (1992) shows the cases where fixed fee licensing could generate more profits to the licensor. However, royalty contracts are generally more visible in industries where IPR protection is stronger (Nagaoka, 2005).[5] So to make the analysis more general, in the present paper we assume two-part tariff licensing contracts which consist of both fee and output-based royalty. However, under the optimal licensing contract it is possible to have one component zero; thus only fee or only royalty in equilibrium is possible. We show that if tariff rate is high, the optimal two-part tariff licensing contract will consist of only fee and zero royalty (hence it is fee licensing). On the other hand, if it is zero, the optimal licensing contract will have only royalty and no fixed fee (so this is royalty licensing). In the intermediate range both fee and royalty will figure in the optimal licensing contracts. When tariffs are prohibitive, the domestic firm will have monopoly under both licensing and no licensing situations.

Then the question is: Which licensing strategy should the local government induce? It depends on the choice of government objective. We consider two alternative objectives, viz., consumers' welfare maximization and domestic (that is, overall) welfare maximization. Accordingly, the government will choose a tariff rate. It also depends on the extent of cost saving due to use of the transferred technology. Therefore, our paper seeks to determine the optimal tariff rate as a function of cost saving (that is, the size of the innovation) under each of these two objectives. The licensing strategy, that is, whether fee licensing, royalty licensing, or fee plus royalty licensing will occur, is endogenously determined.

As far as consumers' welfare maximization is concerned,[6] there is a trade-off between a positive royalty and a positive tariff rate, because both are distortionary in effect. A positive royalty increases the effective cost of the host firm, and a positive tariff raises the effective cost of the foreign firm. In either Case, it has distortionary effect on the industry output; so the product price will be higher compared to zero tariff and zero royalty rate. The problem is that if the tariff rate is zero, royalty licensing will occur (e.g., Wang, 1998), and if fee licensing is to occur, the tariff rate has to be above a critical level. We show that a tariff rate can be strategically chosen so that it induces fee licensing and consumers' welfare is maximum. If the size of the innovation is too small, only in that case it is optimal to set a zero tariff that will induce royalty licensing and consumers' welfare is maximized.

We then consider welfare maximization objective of the government. This is standard in the literature to consider this objective because it recognizes the importance of different broad groups in the society. We derive domestic welfare maximizing tariff and characterize it. We find that fee licensing is always induced at the optimal tariff rate. We also find that the welfare maximizing tariff is higher than the consumers' welfare maximizing tariff if and only if the cost saving under the transferred technology is small.

Finally, we review the commonly held belief that there exists a conflict between the objectives of overall welfare maximization and consumers' welfare maximization. Which policy will the government look for? Equivalently, which group of the society, consumers or producers, be given priority in the development process? This is a debatable issue which is hardly settled in the existing literature. In our paper, however, we show that the so-called conflict will go away if the cost saving due to transferred technology is high enough. The reason is that an appropriate choice of a tariff rate will induce the foreign firm transfer its superior technology to the local firm under a fixed fee contract, hence the distortion that arises due to a positive royalty in the contract will disappear. Therefore, the same tariff that maximizes the overall welfare will also maximize consumers' surplus. However, when the cost saving due to transferred technology is small, the conflict is prominent. Thus, as far as the policy choice is concerned, the government should make sure that the transferred technology is sufficiently cost saving for the local firm.

Note that ours is a theoretical paper, but it contains a number of testable hypothesis. For instance, we establish a relation between the level of tariff and the type of licensing contract. Is there any statistical evidence to prove that low (high) tariffs are closely related to the

[3] Also see the survey on international technology licensing by Wilson (1977) and Saggi (2002). Vishwasrao (2007) has analysed the licensing agreements signed between Indian and foreign firms.

[4] See also Wang (2002), Mukherjee and Balasubramanian (2001), and Fauli-Oller and Sandonis (2002) in this context.

[5] For a detailed discussion on the determinants of patent prices in a licensing contract, see Sakakibara (2010).

[6] To say a few words about the local government's objective of consumers' welfare maximization, note that simple welfare maximization does not mean that consumers will benefit. In particular, in the absence of an effective and meaningful income transfer mechanism, consumers can be the worst suffers. The government in power generally cares the interest of the consumers who, after all, form the largest electorate group. So taking a policy that hurts the consumers, particularly in an election period, is unlikely to be pursued.

number of royalty (fee) contracts? Do we observe fee licensing contracts more frequently in countries with high tariffs? What sort of statistical relation exists between royalty licensing and product price? Thus our paper leaves scope for future statistical analysis.

We shall now briefly outline the literature related to our work. We have already cited some empirical works supporting our assumptions and structure. Here we discuss some theoretical works related to technology licensing, licensing contracts and its impact on welfare, and the related policies. A major part of the literature on optimal licensing contracts discusses the choice between fee licensing and royalty licensing. When the patentee is an outsider and the products are homogeneous, fee licensing dominates royalty licensing, because the surplus under the transferred technology is larger under fee licensing (Kamien and Tauman, 1984, 1986; Katz and Shapiro, 1986; Kamien, 1992; Kamien et al., 1992). On the other hand, when the patentee is an insider, royalty licensing maximizes patentee's profit because under royalty licensing competition from the licensees remains under control (Wang, 1998; Wang and Yang, 1999; Kamien and Tauman, 2002).

The choice between fee and royalty contracts and its welfare implication for the case of horizontally differentiated products are studied in Wang (2002), Mukherjee and Balasubramanian (2001), Fauli-Oller and Sandonis (2002), Erkal (2005) and Li and Ji (2010). Kishimoto and Muto (2012) consider technology licensing when fee or royalty is determined through a process of Nash bargaining. In these papers, generally, royalty licensing dominates fee licensing, but the consumers prefer fee licensing.[7] Muto (1993) and Nguyen et al. (2014), among others, have studied the problem for the case of vertically differentiated products. The optimal licensing contracts and its welfare implication in a leadership structure are discussed in Kabiraj (2004, 2005).[8]

There are a number of works that establish two-part tariff licensing contracts. In an incomplete information framework two-part tariff licensing contracts arise to extract more profits from the licensee (Gallini and Wright, 1990; Beggs, 1992; Schmitz, 2002). Two-part tariff licensing contracts in a complete information framework are also studied in a number of papers. We discuss here only a few. While Sen and Tauman (2007) examine two-part tariff licensing contracts in a general set up of oligopoly with homogeneous goods for both the cases of insider and outsider patentee, Martin and Saracho (2015) have studied the problem in a differentiated duopoly when the patentee is a producing firm; however, royalty can be ad valorem or per unit quantity based.[9] As in Martin and Saracho (2010), in this paper also consumers are hurt under licensing although social welfare is higher. Then Lu and Poddar (2014) have shown that two-part licensing contracts are always optimal if the products are spatially differentiated.[10] Tian (2016), on the other hand, discusses licensing of a quality enhancing innovation to the upstream firm in an upstream-downstream structure from an outside firm. While two-part tariff licensing contracts maximize patentee's profits, but in this paper both the consumers and the society become worse off.

Our present paper deals with two-part licensing contracts and is closely related to Mukherjee (2007), and Poddar and Sinha (2010). 'Trading costs' in Mukherjee (2007) in fact behaves in the same way as tariffs in our paper, because both trading costs and tariffs raise the effective cost of the technology supplier. However, Mukherjee (2007) has not derived the implication of a higher trading cost for the consumers in the context of technology transfer, hence it has not discussed how tariffs can be a policy instrument to induce the licensing strategy of the foreign firm in favor of the consumers of the host country. Various licensing contracts derived in our paper can also be traced in Poddar and Sinha (2010). Whether fee contract or royalty contract or both, depends in their paper on the different cost (in) efficiency levels of the patentee vis-à-vis the licensee. In our paper, by means of tariffs the licensor's effective cost is affected, hence we obtain different licensing contracts for different tariff rates.

Finally, consider some works on trade policy in the context of technology licensing. We have already mentioned that in Kabiraj and Marjit (2003) a tariff is chosen to induce fee licensing and maximize consumers' benefit. Mukherjee and Pennings (2006) have extended this model to the case where the host government can commit its tariff policy. Wang et al. (2012) have also constructed a model of technology transfer from a foreign to a domestic firm but the paper has shown that sometimes consumer friendly initiative on the part of the foreign firm may invite a lower tariff that benefits all parties involved. Ghosh and Saha (2015), on the other hand, have constructed a model of differentiated duopoly with price competition and studied how the optimal trade policy be affected with the possibility of licensing between two firms, from two different countries, which compete in a third country. In their model, the licensor's country becomes worse off under licensing.[11]

Clearly, none of the works cited above discusses the possibility that a tariff can be strategically maneuvered to affect the licensing strategy of the foreign patentee. We show in the present paper that a suitably designed tariff can induce fee licensing. Moreover, if the cost saving under the transferred technology is relatively large, the tariff that maximizes welfare also maximizes consumers' surplus, hence the so-called conflict between the choice of welfare maximization and consumers' surplus maximization can be avoided.

The organization of the paper is the following. Section 2 presents the model and discusses the optimal licensing strategies of the patent holder. Then Section 3 and Section 4 derive the optimal tariffs, maximizing consumers' surplus and welfare, respectively. Section 5 focuses on the possible conflict between these two objectives in respect of the choice of an optimal tariff rate. Finally, Section 6 concludes the paper.

2. Model

Consider a foreign firm and a domestic firm which are competing in quantities a la Cournot in the domestic market. Call these firms firm 1 and firm 2, respectively. The firms produce perfectly substitute goods. The market demand for the product is assumed to be linear and in inverse form given by $P = a - Q = a - (q_1+q_2)$ where P denotes price of the product, Q represents industry output, and a is a demand shift parameter.

Initially, both the firms have unit cost of production $c(0 < c < a)$ constant. Then firm 1 comes up with a new innovation that reduces firm 1's unit cost of production to $c - \varepsilon$, where $\varepsilon > 0$ represents the size of the innovation. We restrict to the assumption that the innovation is non-drastic or minor in the sense that under non-cooperative competition the local firm will always have a positive market share; hence $\varepsilon < a - c$.[12] Further assume that whenever profitable, the firms will be involved in a technology licensing agreement, and under the agreement the foreign firm will license its superior technology to the host firm, and the foreign firm will offer an optimal two-part tariff licensing contract consisting of an upfront fee and a quantity based royalty. However,

[7] Fauli-Oller and Sandonis (2002) have shown the possibility of welfare reducing licensing. This occurs when goods are close substitutes, firms compete in prices and the innovation is large enough.

[8] Sinha (2016) has provided an interesting case of technology transfer from a non-producing firm to an asymmetric duopoly. Here, in equilibrium technology is transferred by means of patent sale to the efficient firm which then licenses the same technology to its product market competitor.

[9] There are a number of papers that discuss the choice between ad valorem and quantity based royalty contracts. For this literature one may look at Bousquet et al. (1998), Martin and Saracho (2010) and Niu (2013).

[10] See Kabiraj and Lee (2011) for optimal licensing contracts in Hotelling structure.

[11] Similar problem is also studied by Ghosh and Saha (2008) in a Cournot duopoly set up.

[12] Since at the same time we need to restrict that $\varepsilon \le c$, with non-drastic innovation we also implicitly assume that $c \ge a - c$, i.e., $c \ge a/2$.

under the optimal contract it is possible to have one component zero, that is, only fee or only royalty positive can be possible. Finally, we assume that the objective of the domestic government is to maximize consumers' welfare or overall social welfare, hence the government likes to influence the licensing strategy of the patent holder by means of manipulating its policy instrument, here the tariff rate, $\tau \geq 0$, on foreign products. So the domestic government will choose the tariff rate strategically to reach the respective objective.

The sequence of moves in the game is the following. In the first stage the local government commits a tariff rate $\tau \in [0, \infty)$ per unit of foreign products with an objective to maximize consumers' welfare or overall welfare, as may be the case. In the second stage, given $\tau \geq 0$, the foreign firm decides its licensing strategy and offers a two-part tariff licensing contract $T(F, r)$ to the host firm where $F(\geq 0)$ is the fixed fee and $r(\geq 0)$ is the royalty per unit. The host firm accepts the contract if it is not worse off. In the third and final stage, given the technological configuration at the end of the second stage, the firms compete in quantities in a Cournot fashion. We solve the game by backwards induction. In the following subsection we consider no licensing equilibrium as a benchmark case. Then in the next subsection we derive the optimal licensing contracts.

2.1. No licensing

Given the assumption of non-drastic innovation (i.e.,$\varepsilon < a - c$), for any non-prohibitive tariff $\tau \geq 0$ under no licensing equilibrium the Cournot quantities of the firms are:

$$q_1^{NL} = \frac{a - c + 2\varepsilon - 2\tau}{3} \text{ and } q_2^{NL} = \frac{a - c - \varepsilon + \tau}{3} \tag{1}$$

and profits are

$$\pi_1^{NL} = \frac{(a - c + 2\varepsilon - 2\tau)^2}{9} \text{ and } \pi_2^{NL} = \frac{(a - c - \varepsilon + \tau)^2}{9} \tag{2}$$

The above expressions are subject to the assumption that tariffs are non-prohibitive, that is,

$$0 \leq \tau < \frac{a - c + 2\varepsilon}{2} \tag{3}$$

When tariffs are prohibitive, i.e., $\tau \geq \frac{a-c+2\varepsilon}{2}$, the local firm will emerge as a monopolist.

2.2. Optimal licensing contracts

Consider licensing under the two-part tariff contract $T(F, r)$. Under licensing the per unit cost configurations of firm 1 and firm 2 are, respectively, $(c - \varepsilon + \tau)$ and $(c - \varepsilon + r)$. Then Cournot competition will lead to the following output levels,

$$q_1^T = \frac{a - c + \varepsilon - 2\tau + r}{3} \text{ and } q_2^T = \frac{a - c + \varepsilon + \tau - 2r}{3} \tag{4}$$

The corresponding market operated profits of the firms are

$$\pi_1^T = \frac{(a - c + \varepsilon - 2\tau + r)^2}{9} \text{ and } \pi_2^T = \frac{(a - c + \varepsilon + \tau - 2r)^2}{9} \tag{5}$$

Hence the problem of designing the optimal two-part licensing contract comprises of the following constrained maximizing problem,

$$Max_{r,F}\, \pi_1^T + rq_2^T + F$$

$$\text{s. t.} \quad F \leq \pi_2^T - \pi_2^{NL} \tag{C1}$$

$$F \geq 0 \tag{C2}$$

$$r \geq 0 \tag{C3}$$

Since in equilibrium (C1) must be satisfied with strict equality, hence

$$F = \pi_2^T - \pi_2^{NL} \equiv F(r)$$

Now, $\pi_2^T \geq \pi_2^{NL}$ iff $q_2^T \geq q_2^{NL}$, i.e., $r \leq \varepsilon$. Hence,

$$F \geq 0 \quad \Leftrightarrow r \leq \varepsilon$$

Then the above problem reduces to

$$Max_r\, \pi_1^T + rq_2^T + F(r) \text{ s. t.} \quad r \in [0, \quad \epsilon] \tag{6}$$

Let us define

$$\hat{r} = \frac{a - c + \varepsilon - 5\tau}{2} \tag{7}$$

The following proposition then defines the optimal licensing contracts.

Proposition 1. The optimal licensing contracts $T(F^*, \quad r^*)$ under two part tariffs consist of the following:

(a) $F^* = 0, \quad r^* = \varepsilon$ *whenever* $\tau \leq \frac{a-c-\varepsilon}{5}$;
(b) $F^* = F(\hat{r}), \quad r^* = \hat{r} < \varepsilon$ *if* $\frac{a-c-\varepsilon}{5} < \tau < \frac{a-c+\varepsilon}{5}$;
(c) $F^* = F(0), \quad r^* = 0$ *if* $\geq \frac{a-c+\varepsilon}{5}$.

Proof. See Appendix. □

Note that when tariffs are prohibitive (i.e., $\tau \geq \frac{a-c+2\varepsilon}{2}$), the optimal licensing contract is just the fee licensing contract. Therefore, the second stage outcome is that if the tariff rate is low enough (i.e., $\tau \leq \frac{a-c-\varepsilon}{5}$), the optimal licensing contract consists of royalty only, and the optimal royalty rate is ε; if the tariff rate is large (i.e., $\tau \geq \frac{a-c+\varepsilon}{5}$), the optimal licensing contract consists of fee only; in the intermediate range, however, the optimal licensing contract consists of both fee and royalty, with royalty rate $\hat{r}(<\varepsilon)$ and fee $F(\hat{r}) > 0$.

Intuition of the result is the following. Under non-prohibitive tariff, both domestic and foreign firms compete in the same (here domestic) product market. In the pre-licensing situation, the domestic firm operates with its inefficient technology. So when the foreign firm transfers its superior technology to its product market competitor, it makes the domestic firm efficient and competitive. The increased payoff of the domestic firm can however be extracted by the foreign firm by a fixed fee for the transferred technology. But under technology transfer since the domestic firm becomes now more efficient, it hurts the payoff of the foreign firm from its market operation. Hence to reduce or check the competitive prowess of the transferee, the foreign firm charges a royalty per unit which raises the effective unit cost of the domestic firm. While the domestic firm becomes less competitive under a positive royalty and the foreign firm gets an income in the form of royalty from the transferee, but it now generates less surplus for the domestic firm, hence the less amount could be extracted by the foreign firm. Thus there is a trade-off between a royalty and a fixed fee. Now if the tariff is high, the foreign firm's effective cost will be high, so in the post-transfer situation it has no much to suffer from competition from the rival; hence for the foreign firm charging only fee and no royalty is more profitable. In the opposite case when tariffs are low, so that the competition from the domestic rival will reduce the foreign firm's payoff from operation to a sufficient amount, then restraining the competitiveness of the domestic firm by means of a royalty is more profitable for the foreign firm. Therefore, when tariffs are neither too high nor too low, a combination of a fixed fee and a royalty will be optimal for the foreign firm to charge for the transferred technology.

The results are portrayed in Fig. 1. We have drawn three lines, $\tau = \frac{a-c+2\varepsilon}{2}$, $\tau = \frac{a-c+\varepsilon}{5}$ and $\tau = \frac{a-c-\varepsilon}{5}$ in the figure. These are given by the lines DE, AC and AB, respectively. Then, all points on and above the line DE represent the scenario of prohibitive tariffs and the points below the line represent non-prohibitive tariffs scenario. Then for all points on and above the line AC the optimal two-part tariff licensing contract consists of only fixed fee and zero royalty, and for all points on and below the line AB the optimal licensing contract consists of only royalty rate (equal to cost saving) and zero fixed fee. The licensing

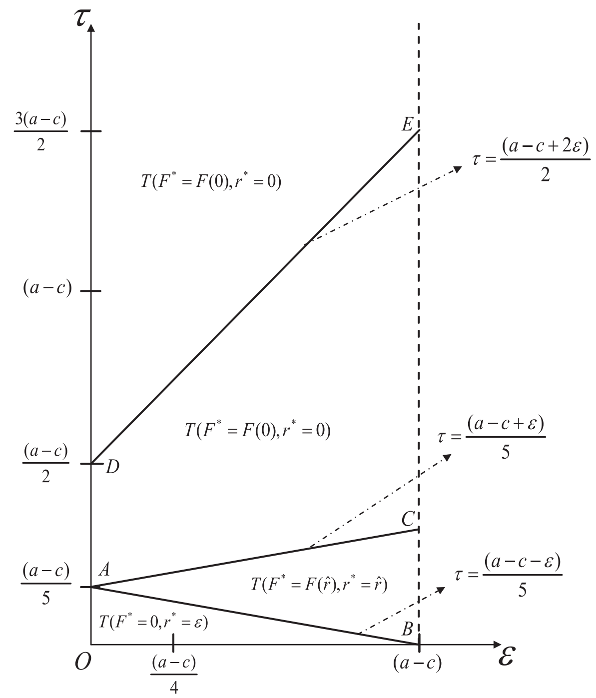

Fig. 1. Optimal licensing contracts for different values of τ and ε.

contracts have both components positive for all (ε, τ) lying in between the lines AB and AC, and here the royalty rate is less than the amount of cost saving.

3. Consumers' welfare and the optimal tariff rate

In this section we assume that the objective of the domestic government is to maximize consumers' welfare which is measured by consumers' surplus (CS). With the linear demand function, $CS = \frac{1}{2}Q^2$. Therefore, maximizing consumers' welfare is equivalent to maximizing industry output under different scenarios defined by different values of τ, given any $\varepsilon \in (0, a - c)$. The maximum possible industry outputs under various scenarios are given below.

(a) *No Licensing*: Under no licensing scenario the industry output is $Q^{NL}(\tau) = q_1^{NL} + q_2^{NL} = \frac{1}{3}[2(a - c) + \varepsilon - \tau]$. Therefore,

$$Max_\tau Q^{NL}(\tau) = \frac{1}{3}[2(a-c)+\varepsilon] \equiv \overline{Q}^{NL} \tag{8.a}$$

(b) *Prohibitive Tariff Regime*: Suppose $\tau \geq \frac{a-c+2\varepsilon}{2}$. Then the local firm will have monopoly and then only fixed fee will be charged for the transferred technology. Hence the industry output under prohibitive tariff will be $Q^M(\tau) = \frac{1}{2}[a - c + \varepsilon]$ which is independent of τ. Therefore,

$$Max_\tau Q^M(\tau) = \frac{1}{2}[a - c + \varepsilon] \equiv \overline{Q}^M \tag{8.b}$$

(c) *Fee Licensing*: Suppose $\tau \in [\frac{a-c+\varepsilon}{5}, \frac{a-c+2\varepsilon}{2})$. Here licensing occurs with only fee and zero royalty. Then the industry output is $Q^{T(F(0),0)}(\tau) = \frac{1}{3}[2(a - c) + 2\varepsilon - \tau]$ which is falling in τ; hence

$$Max_\tau Q^{T(F(0),0)}(\tau) = Q^{T(F(0),0)}\left(\tau = \frac{a - c + \varepsilon}{5}\right) = \frac{3(a - c + \varepsilon)}{5} \equiv \overline{Q}^F \tag{8.c}$$

(d) *Fee plus Royalty Licensing*: Suppose $\tau \in (\frac{a-c-\varepsilon}{5}, \frac{a-c+\varepsilon}{5})$. Here the optimal licensing contract consists of both fee and royalty, $F(\hat{r})$ and $\hat{r}(<\varepsilon)$. The industry output under this scenario is $Q^{T(F(\hat{r}),\hat{r})}(\tau) = \frac{1}{2}[(a - c) + \varepsilon + \tau]$. Interestingly, in this scenario the industry output goes up as τ increases. The reason is that as τ increases, the optimal royalty rate, $\hat{r}$, falls more (see (7)). Since $Lim_{\tau \to \frac{a-c+\varepsilon}{5}} Q^{T(F(\hat{r}),\hat{r})}(\tau) = \frac{3(a-c+\varepsilon)}{5}$, therefore

$$Max_\tau Q^{T(F(\hat{r}),\hat{r})}(\tau) < \overline{Q}^F \tag{8.d}$$

(e) *Royalty Licensing*: Finally, consider $\tau \in [0, \frac{a-c-\varepsilon}{5}]$. Here the optimal licensing contract consists of zero fixed fee and royalty rate ε. Then the industry output under this scenario is $Q^{T(0,\ \varepsilon)}(\tau) = \frac{1}{3}[2(a - c) + \varepsilon - \tau]$ which is falling in τ; hence

$$Max_\tau Q^{T(0,\ \varepsilon)}(\tau) = Q^{T(0,\ \varepsilon)}(\tau = 0) = \frac{2(a - c) + \varepsilon}{3} \equiv \overline{Q}^{R(\varepsilon)} \tag{8.e}$$

Now comparing the different maximum levels of outputs under different scenarios, we have

$$\overline{Q}^F > Max_\tau Q^{T(F(\hat{r}),\hat{r})}(\tau) > \overline{Q}^M, \text{ but } \overline{Q}^F \geq \overline{Q}^{R(\varepsilon)} \text{ if } f\varepsilon \geq \frac{a - c}{4} \tag{9}$$

Hence we can write the following proposition.

Proposition 2. Given any $\varepsilon \in (0, \quad a-c)$, (i) if $\varepsilon < \frac{a-c}{4}$, consumers' welfare maximizing tariff rate is $\tau^*=0$ which induces royalty licensing with royalty rate ε, and (ii) for all other values of ε the optimal tariff rate is $\tau^* = \frac{a-c+\varepsilon}{5}$ which induces fee licensing.

Thus our result shows that if the size of the innovation is small (i.e., $0 < \varepsilon < \frac{a-c}{4}$), then the optimal licensing contract is $T(F^*=0, r^*=\varepsilon)$ and $\tau^*=0$. On the other hand, if the size of the innovation is relatively large (i.e., $\varepsilon \geq \frac{a-c}{4}$), a suitably designed tariff results in a licensing contract with fee only and no royalty. Here consumers derive the full benefit of the efficient technology. Intuition of the result is the following. There is a trade-off between tariffs and quantity based royalties. On one hand, without a tariff we have royalty licensing that distorts the cost of the domestic firm. On the other hand, a high enough tariff is required to have fixed fee licensing so that we have distortion on the cost of the foreign firm. Then the size of the innovation determines which tariff rate maximizes consumers' welfare. When innovation is large, the first distortion is more critical than the second one so that a positive tariff is imposed in order to induce technology licensing through a fixed fee contract.

4. Overall welfare and the optimal tariff rate

In this section we assume that instead of maximizing consumers' surplus, the objective of the domestic government is to maximize the overall welfare which consists of consumers' surplus, domestic firm's net profit and tariff revenue of the government. First we derive optimal tariffs in different licensing regimes, given any efficiency level of the transferred technology. Then we discuss how the tariff rate can be manipulated inducing the optimal licensing strategy, from the perspective of the local country, that maximizes domestic welfare. In the next section we then provide a comparative discussion on consumers' surplus vs. welfare maximization policy.

Note that the licensing strategy of the foreign firm is stated in Proposition 1 for any tariff rate chosen by the local government at the first stage. Then under the optimal contract, the foreign firm extracts all surplus of the local firm by means of a fee or royalty or both. Hence the local firm can just retain its pre-licensing payoff, π_2^{NL} in the post-licensing situation.

Regime 1. Royalty Licensing: $(F^*=0, \quad r^*=\varepsilon)$

This regime is described by the tariff interval $0 \leq \tau \leq \frac{a-c-\varepsilon}{5}$ which induces the foreign firm to charge a zero fixed fee but a royalty rate $r^*=\varepsilon$ by which the foreign firm extracts all surplus of the local firm. Under this (royalty) regime, the industry output is $Q^R = \frac{2(a-c)+\varepsilon-\tau}{3}$ and the foreign firm's output is $q_1^R = \frac{a-c+2\varepsilon-2\tau}{3}$. Hence the welfare expression in this regime is given by,

$$W_1(\tau;\varepsilon)=\frac{1}{2}\left[\frac{2(a-c)+\varepsilon-\tau}{3}\right]^2+\frac{(a-c-\varepsilon+\tau)^2}{9}+\tau\left(\frac{a-c+2\varepsilon-2\tau}{3}\right) \tag{10}$$

Then the optimal tariff, in this regime, as a function of the efficiency level of the transferred technology, is derived to be,[13]

$$\tau_1^{**}=\frac{a-c-\varepsilon}{5} \tag{11}$$

This means, $W_1(\tau_1^{**};\varepsilon)\geq W_1(\tau;\varepsilon)\quad\forall\quad\tau\in[0,\quad\frac{a-c-\varepsilon}{5}]$

Regime 2. Two-Part Tariff Licensing: $(F^*=F(\hat{r}),\quad r^*=\hat{r}<\varepsilon)$

This regime is specified by the interval $\frac{a-c-\varepsilon}{5}<\tau<\frac{a-c+\varepsilon}{5}$, and the corresponding optimal licensing contract is the two-part tariff consisting of the royalty rate $\hat{r}\,(<\varepsilon)$ and the fixed fee $F^*=F(\hat{r})$. Then, in this regime the industry output is $Q^T=\frac{a-c+\varepsilon+\tau}{2}$ and the foreign firm's output is $q_1^T=\frac{a-c+\varepsilon-3\tau}{2}$. Hence the welfare expression is,

$$W_2(\tau;\,\varepsilon)\,=\,\frac{1}{2}\left[\frac{a-c+\varepsilon+\tau}{2}\right]^2+\frac{(a-c-\varepsilon+\tau)^2}{9}+\tau\left(\frac{a-c+\varepsilon-3\tau}{2}\right) \tag{12}$$

It can easily be checked that the function $W_2(\tau;\varepsilon)$ is increasing in τ over its domain. Since the domain is open, so there is no maximum. Let $Lim_{\tau\to\tau_2^{**}\equiv\frac{a-c+\varepsilon}{5}}W_2(\tau;\varepsilon)=W_2(\tau_2^{**};\varepsilon)$; this means, the maximum welfare of this regime cannot exceed $W_2(\tau_2^{**};\varepsilon)$.

Regime 3. Fee Licensing: $(F^*=F(0),\quad r^*=0)$

This regime is defined for $\frac{a-c+\varepsilon}{5}\leq\tau<\frac{a-c+2\varepsilon}{2}$, and such a tariff induces fee licensing (with royalty rate zero).[14] In this regime the industry output is $Q^F=\frac{2(a-c+\varepsilon)-\tau}{3}$ and the foreign firm's output is $q_1^F=\frac{a-c+\varepsilon-2\tau}{3}$. Hence the welfare expression is,

$$W_3(\tau;\varepsilon)=\frac{1}{2}\left[\frac{2(a-c+\varepsilon)-\tau}{3}\right]^2+\frac{(a-c-\varepsilon+\tau)^2}{9}+\tau\left(\frac{a-c+\varepsilon-2\tau}{3}\right) \tag{13}$$

Then the optimal tariff in this regime can be solved as

$$\tau_3^{**}=\begin{cases}\hat{\tau}_3^{**}\equiv\frac{3(a-c)-\varepsilon}{9}\text{ if }\varepsilon<\frac{3(a-c)}{7}\\ \tilde{\tau}_3^{**}\equiv\frac{a-c+\varepsilon}{5}\text{ if }\varepsilon\geq\frac{3(a-c)}{7}\end{cases} \tag{14}$$

Note that $\tilde{\tau}_3^{**}=\tau_2^{**}$ for $\varepsilon\geq\frac{3(a-c)}{7}$. Therefore, $W_3(\tau_3^{**};\varepsilon)\geq W_3(\tau;\varepsilon)$.

The optimal tariffs are stated in the following lemma.

Lemma 1. The welfare maximizing tariffs in regime 1 and 3 are respectively τ_1^{**} and τ_3^{**} (as given in expression (11) and (14)). The welfare maximizing tariff in regime 2 does not exist.

The optimal tariffs in different regimes are depicted in Fig. 2 by the heavy line.

We are now in a position to derive the optimal welfare maximizing tariff rate internalizing its effect on the choice of licensing strategy of the foreign firm.

We have already derived that the welfare maximizing tariff in regime 1 is τ_1^{**}, therefore, $W_1(\tau_1^{**};\varepsilon)\geq W_1(\tau;\varepsilon)\forall\;\tau\in[0,\;\frac{a-c-\varepsilon}{5}]$. Then given the definition of regime 2, we must have $W_2(\tau_1^{**};\varepsilon)=W_1(\tau_1^{**};\varepsilon)$ and $W_2(\tau;\varepsilon)$ is increasing in τ over its domain. Therefore, $W_2(\tau;\varepsilon)>W_1(\tau_1^{**};\varepsilon)\quad\forall\;\tau\in(\frac{a-c-\varepsilon}{5},\quad\frac{a-c+\varepsilon}{5})$, that is, regime 2 strictly dominates regime 1 in terms of welfare. We have already noted that the regime 2 welfare cannot exceed $W_2(\tau_2^{**};\varepsilon)$. But note that the tariff rate τ_2^{**} belongs to regime 3, hence at least $W_2(\tau_2^{**};\varepsilon)$ level of welfare is achievable in regime 3 (actually, $W_3(\tau_2^{**};\varepsilon)=W_2(\tau_2^{**};\varepsilon)$). This means, the overall maximum welfare will be traced in regime 3. We have already derived that $W_3(\tau_3^{**};\varepsilon)\geq W_3(\tau;\varepsilon)\quad\forall\;\tau\in[\frac{a-c+\varepsilon}{5},\quad\frac{a-c+2\varepsilon}{2})$.

First assume that $\varepsilon\geq\frac{3(a-c)}{7}$. Then from (14), the optimal tariff in regime 3 is $\tau_3^{**}=\tilde{\tau}_3^{**}$; however, it happens to be that $\tilde{\tau}_3^{**}=\tau_2^{**}$. Therefore, the maximum possible welfare that can be achieved by manipulating τ is $W_3(\tilde{\tau}_3^{**};\varepsilon)$, given any $\varepsilon\geq\frac{3(a-c)}{7}$. So, if the efficiency level of the transferred technology is sufficiently large, the overall welfare maximizing tariff rate will be $\tilde{\tau}_3^{**}\equiv\frac{a-c+\varepsilon}{5}$. Now consider the assumption that $\varepsilon<\frac{3(a-c)}{7}$. Then given (14), we must have $W_3(\hat{\tau}_3^{**};\varepsilon)\geq W_2(\tau_2^{**};\varepsilon)$ implying that overall welfare is maximized at a tariff rate $\hat{\tau}_3^{**}$ for $\varepsilon<\frac{3(a-c)}{7}$.

To summarize, if we denote the overall welfare maximizing tariff by τ^{**}, then we have,

$$\tau^{**}=\begin{cases}\hat{\tau}_3^{**}\equiv\frac{3(a-c)-\varepsilon}{9}\text{ if }\varepsilon<\frac{3(a-c)}{7}\\ \tilde{\tau}_3^{**}\equiv\frac{a-c+\varepsilon}{5}\text{ if }\varepsilon\geq\frac{3(a-c)}{7}\end{cases} \tag{15}$$

We can then write the following proposition.

Proposition 3. If the objective of the local government is to maximize the overall welfare, it will choose a tariff rate τ^{**} that will induce the foreign firm transfer its technology under the fee contract. As the size of the innovation ε becomes larger, the optimal tariff first falls then increases.

Note that welfare maximization occurs at a tariff rate that induces fee licensing. This is for the simple reason that under royalty licensing (which would occur at a relatively lower tariff rate) consumers would have a loss of surplus due to distortion in pricing for a positive royalty. While the domestic firm has nothing to gain compared to no licensing situation, but a positive tariff means that the domestic firm has higher than no-licensing payoff. Finally, compared to zero tariff a positive tariff always increases welfare because the government revenue also becomes positive. Under optimal tariffs, although there is distortion, but an appropriate tariff induces fee licensing and maximizes welfare.

To explain why initially optimal tariff falls as the efficiency of the

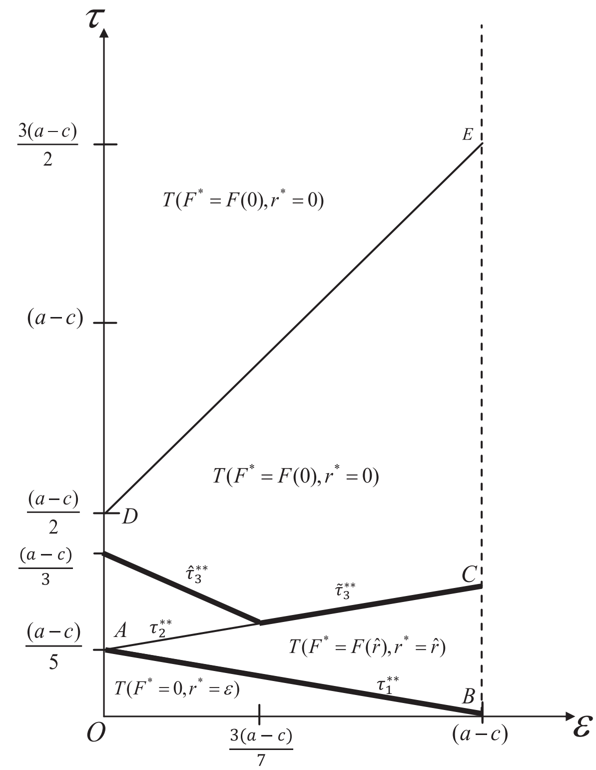

Fig. 2. Welfare maximizing tariffs in different regimes.

[13] The unconstrained optimization of (10) would yield $\tau=\frac{a-c+\varepsilon}{3}>\frac{a-c-\varepsilon}{5}$.

[14] Note that in case of a prohibitive tariff, i.e., for $\tau\geq\frac{a-c+2\varepsilon}{2}$, we have the same licensing contract $(F(0),\,0)$, but this is the case of domestic firm's monopoly; hence the corresponding welfare expression is $W_0=\frac{1}{2}\left[\frac{a-c+\varepsilon}{2}\right]^2+\frac{(a-c)^2}{4}$ which is independent of τ.

transferred technology (ε) increases, note that when ε is small, the welfare maximizing tariff is higher than the minimum tariff required to induce fee licensing. Now as ε goes up initially, tariff revenue goes up by lowering the tariff so long it is below a critical level. While it reduces domestic profit to some extent, consumers gain due to higher ε and lower tariff. However, when ε is large enough, consumers' surplus is also large and a mild increase in tariff raises tariff revenue as well as local profit, and this dominates the loss of consumer surplus due to increase in tariff.

5. Policy issue: consumers' surplus vs. welfare maximization

It is commonly believed that a tariff when chosen generally enhances social welfare, but more often than not it hurts the consumers, because the consumers face a higher price of the product under tariffs. This belief however does not take into account the possibility that a tariff, if strategically chosen, may induce the foreign firm transfer its technology with an appropriate licensing contract that is beneficial to the consumers. Moreover, our paper shows, there are situations when there is in fact no conflict between the objectives of welfare maximization and consumers' surplus maximization.

From the analysis of the last two sections it is now clear that the choice of an optimal tariff rate depends not only on the efficiency level of the transferred technology but also on the objective of the local government. Generally, a tariff policy brings tariff revenue for the government and protects the local firms from foreign competition, but to the criticism that a tariff may affect the interest of the consumers adversely, the government defends the policy stating that the overall welfare is higher under the tariff regime. But our analysis shows that not always there is a conflict between the objectives of consumers' welfare maximization and overall welfare maximization. One important contribution of the paper, that is never taken into account in the literature, is that the tariff can be an instrument to influence the licensing strategy of the foreign firm. A suitably designed tariff can induce the foreign firm transfer its technology under the fee contract, and hence the negative effect of imposing a positive royalty can be bypassed. Then if the efficiency level of the transferred technology is above a critical level (i.e., $\varepsilon \geq \frac{3(a-c)}{7}$), our paper shows that the tariff that maximizes social welfare also maximizes consumer surplus (see Propositions 2 and 3), hence in this case there is no conflict between the two objectives of the government. The government is also satisfied with the tariff revenue. However, the conflict between the two objectives will be very prominent when the efficiency of the transferred technology is too small (i.e., $\varepsilon < \frac{a-c}{4}$). Here consumers' welfare maximization involves a zero tariff which induces royalty licensing, whereas welfare maximization involves a high tariff, $\tau = \frac{3(a-c)-\varepsilon}{9}$. So consumers become worse off in this situation. When the size of the innovation is moderate (i.e., $\frac{a-c}{4} < \varepsilon < \frac{3(a-c)}{7}$), there is also conflict of interest but it is less prominent, because consumers' surplus maximizing tariff is $\frac{a-c+\varepsilon}{5}$ and the welfare maximizing tariff is $\frac{3(a-c)-\varepsilon}{9}$ (in either case, however, the royalty rate is zero). Under the optimal tariff policy when the tariff induces an appropriate licensing contract, neither the consumers' surplus nor the overall welfare is less compared to no licensing equilibrium, hence a suitably designed tariff plays an important role. Finally, compared to a prohibitive tariff, a suitably designed tariff can bring a higher welfare for both consumers and nation.

We summarize the discussion in the following proposition.

Proposition 4. If the cost saving under the transferred technology is high enough, the same tariff maximizes both consumers' surplus and overall welfare; otherwise, there is a conflict between the two objectives of the government regarding the choice of an optimal tariff rate.

6. Conclusion

This paper discusses the possibility of having an enhanced consumers' surplus as well as social surplus by means of a suitably designed tariff policy. We have raised this issue in a framework of asymmetric duopoly where the foreign firm possesses the superior production technology compared to the technology of the home firm, and whenever profitable the firms make a licensing agreement under which the foreign firm licenses its superior technology to the home firm. It is assumed that the foreign firm designs an optimal two-part tariff licensing contract comprising of a fixed fee and a royalty. However, under the optimal contract one component can be zero. In the absence of any intervention by the local government, the optimal contract consists of only royalty and zero fixed fee, but under prohibitive tariff the optimal contract will have only fee and no royalty. We have shown that there are situations when tariffs are positive and non-prohibitive for which both fee and royalty can be positive. Thus our paper highlights the fact that a tariff can be an effective instrument to influence the licensing strategy of the foreign firm. In particular, the government can implement fee licensing contract by means of its appropriate choice of tariffs.

In the paper we have considered two alternative objectives of the local government, namely, consumers' welfare maximization and social welfare maximization. Consumers' welfare is measured by consumers' surplus, and social welfare consists of consumers' surplus, domestic firm's profit and government's tariff revenue. We have also examined whether there is any conflict between these two objectives as far as the choice of an optimal tariff is concerned.

When consumers' welfare maximization is the objective of the local government, we have noted the trade-off between a positive royalty and a positive tariff. Our paper shows that the local government can influence the licensing strategy of the foreign firm by means of manipulating the tariff rate and hence optimally choose a tariff that maximizes consumers' welfare. In particular, we have shown that if the size of the innovation is small, consumers' welfare maximizing tariff will be zero and this will induce licensing with a royalty rate equal to the amount of cost saving. On the other hand, when the size of the innovation is large, an appropriate tariff rate will induce a licensing agreement with a fee only. This will lead to a higher consumers' surplus compared to no licensing situation and prohibitive tariff regime. In our framework when a tariff is chosen to maximize consumers' welfare, this also results in a higher social welfare because the local firm gains from its higher reservation payoff under the tariff, and the local government also acquires a part of the foreign firm's profit in the form of tariff revenue.

Then we have derived the welfare maximizing (optimal) tariff as a function of the size of the innovation (which is the efficiency level of the transferred technology). Fee licensing is induced at an optimal tariff, given any efficiency level of the transferred technology. It may be noted that for consumers' welfare maximization, royalty licensing is induced (by a zero tariff) when the size of the innovation is too small. Welfare maximizing tariffs are generally higher than consumers' welfare maximizing tariffs, provided that the efficiency level of the transferred technology is not too large. Interestingly, the optimal tariff first falls then rises as the size of the innovation goes up.

Finally, we have discussed whether there is any conflict between these two objectives regarding the choice of a tariff. When the government seeks to maximize the overall welfare of the country, at the optimal tariff generally consumers become worse off. Based on this, welfare maximizing objective of the government is often criticized because such a tariff brings tariff revenue for the government and protects the domestic firms from foreign competition, but this is at the cost of the consumers. This conjecture is true also in our paper as long as the size of the innovation is small. However, if the size of the innovation is above a critical level, the so-called conflict between these two objectives just vanishes. Here we have shown that the same tariff maximizes both social welfare and consumers' surplus. Therefore, the government needs to make sure that the efficiency level of the transferred technology is not too small.

As for future research note that in the present analysis we have assumed that tariff is the only instrument by which the local government can achieve its objective. Future research may then take into account the other possible policy variables relevant in this context. Then in the paper we have established a number of relationships theoretically. This leaves scope for empirical research. Perhaps the future applied researchers can verify whether these relations are also established by statistical evidences.

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We shall, however, be held responsible for any remaining errors.

Appendix

The problem stated in (6) is:

$$Max_r \Longleftrightarrow \Omega_1 = \frac{(a-c+\varepsilon-2\tau+r)^2}{9} + \frac{3r(a-c+\varepsilon+\tau-2r)}{9} + \left[\frac{(a-c+\varepsilon+\tau-2r)^2}{9} - \frac{(a-c-\varepsilon+\tau)^2}{9}\right]$$

s. t. $r \le \varepsilon$ and $r \ge 0$.

If λ_1 and λ_2 be the Lagrangian multipliers associated with the two constrains, the Kuhn-Tucker conditions to this problem are:

$$\frac{\partial \Omega_1}{\partial r} - \lambda_1 + \lambda_2 = 0$$

$$\lambda_1, \quad \lambda_2 \ge 0, r \le \varepsilon, \quad r \ge 0$$

$$\lambda_1(\varepsilon - r) = 0, \quad \lambda_2 r = 0$$

Case (i). Suppose $\lambda_1 = 0 = \lambda_2$. Then $\frac{\partial \Omega_1}{\partial r} = 0$, $\varepsilon \ge r$ and $r \ge 0$. Now, $\frac{\partial \Omega_1}{\partial r} = 0 \Leftrightarrow r = \frac{a-c+\varepsilon-5\tau}{2} = \hat{r}$. Therefore, $\hat{r} > 0$ iff $\tau < \frac{a-c+\varepsilon}{5}$, and $\hat{r} < \varepsilon$ iff $\tau > \frac{a-c-\varepsilon}{5}$. Hence when $\in (\frac{a-c-\varepsilon}{5}, \quad \frac{a-c+\varepsilon}{5})$, the optimal licensing contract becomes $r^* = \hat{r}$, $F^* = F(\hat{r})$.

Case (ii). Suppose $\lambda_1 > 0$, $\lambda_2 = 0$. Then $r = \varepsilon > 0$ and $\frac{\partial \Omega_1}{\partial r} - \lambda_1 = 0 \Leftrightarrow \lambda_1 = \frac{a-c-\varepsilon-5\tau}{9}$, and $\lambda_1 > 0 \Rightarrow \tau < \frac{a-c-\varepsilon}{5}$. Hence $r^* = \varepsilon$ if $\tau < \frac{a-c-\varepsilon}{5}$, and correspondingly $F^* = 0$.

Case (iii). Suppose $\lambda_1 = 0$, $\lambda_2 > 0$. Then $r = 0$ and $\frac{\partial \Omega_1}{\partial r} + \lambda_2 = 0 \Rightarrow 9\lambda_2 = -(a-c+\varepsilon-5\tau)$. Therefore, $\lambda_2 > 0$ iff $(a-c+\varepsilon-5\tau) < 0 \Rightarrow \tau > \frac{a-c+\varepsilon}{5}$. Hence $r^* = 0$ and $F^* = F(0)$ if $\tau > \frac{a-c+\varepsilon}{5}$.

Finally, note that the case of $\lambda_1 > 0, \lambda_2 > 0$ cannot arise, given the Kuhn-Tucker conditions. ■

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