Monograph:

Brown, H., Hole, A.R. and Roberts, J. (2010) Strategic Behaviour of Firms in a Duopoly and the Impact of Extending the Patenting Period. Working Paper. Department of Economics, University of Sheffield ISSN 1749-8368

Sheffield Economic Research Paper Series 2010014

Sheffield Economic Research Paper Series

SERP Number: 2010014

ISSN 1749-8368

Tapan Biswas[†] and Jolian McHardy[‡]

[†]Senior Fellow, RCEA, Rimini, Italy and Fellow, University of Hull, Centre for Economic Policy, Hull, UK
[‡]Department of Economics, University of Sheffield, U.K. and Fellow, RCEA, Rimini, Italy.

STRATEGIC BEHAVIOUR OF FIRMS IN A DUOPOLY AND THE IMPACT OF EXTENDING THE PATENTING PERIOD

JUNE 2010

Department of Economics
University of Sheffield
9 Mappin Street
Sheffield
S1 4DT
United Kingdom
www.shef.ac.uk/economics

Abstract

This paper deals with strategic behaviour of firms in a duopoly, subsequent to the claim by one firm that it has reduced the unit cost of production. A variety of possible strategic equilibria are discussed in the context of a duopoly game between a multinational and a local firm. In the context of an extended uniform period of patenting, as finally agreed in the Uruguay round (1994), firms have increased incentive to take patents. In the presence of cost differences, the act of taking process-patents has implications for the equilibrium output strategies of the duopoly firms and sometimes may have a negative overall welfare effect for the local producer and consumers.

Keywords: Asymmetric Information, Duopoly, Process Patenting, Repeated Games
JEL codes: O12, D23, 034, D43
Acknowledgements: An earlier draft of the paper was presented at the University of Bologna, University of Paris 1 (Sorbonne) and at the University of Brunel. The authors are indebted to the participants for suggestions and comments.

1 Introduction

The Final Act of the Uruguay Round laid down the regulations on patenting rights as a part of the TRIP (Trade Related Intellectual Property Rights) agreement. This established a uniform patenting period (both for final products and the processes) of 20 years for the member countries. For many developing countries this meant a considerable extension of the existing patenting period. This extension of the patenting period was opposed by several developing countries. In the end, it was accepted as a part of the final agreement which, on the whole, was believed to offer a better prospect for the trading world. The developing countries were allowed a reasonable period to adjust their patent laws to suit the agreement. The arguments in favour of and against patenting or an extension of the patenting period are well known (e.g., see Penrose, 1973) and are not repeated here. In this paper we examine a possible implication of the extension of the period of process patenting affecting the producers and consumers of a developing economy.

The decision to take a patent depends on a number of variables. However, it is well agreed by economists that the length of patenting period is a major factor affecting the decision to take a patent. A longer period of patenting encourages cost-efficient multinationals to take patents on production processes and increases available information in the market to fence off competition from less-efficient producers. When the period of patenting is short, firms may prefer secrecy to patents (see Lunn, 1987). For example, the Indian government took a drastic measure in 1970 to reduce the patenting period and abolished product patents on chemical products causing a substantial drop in the rate of patenting (see Bagchi *et al.*, 1984; Deolalikar & Röller, 1989).

However, the change in the level of information resulting from a patent may affect the market in such a way that both the producers and consumers in a developing country are worse off. This paper demonstrates this possibility in the context of a duopoly model with asymmetric information on costs. Sakai (1985), following Ponssard (1976, 1979), points out that in a Cournot duopoly with incomplete cost information, the value of information to a firm may be negative. For a similar result see Gal-Or (1988). Mirman *et al.* (1994) point out that, in the presence of demand uncertainties, the duopoly firms may gain through manipulating information by giving false signals. Mirman *et al.* (1993) discuss the problem of signal jamming. This paper builds on the idea that the possibility of information manipulation through output signalling may result in a pooling equilibrium from which the local firms in a developing economy may profit. A longer period of patenting will increase the possibility of patenting by relatively cost-efficient multinationals, thereby providing more information regarding the process of production and the production costs of the multinationals. In the context of a Cournot duopoly with a negative value of information, this may have adverse effects on the producers and consumers in a developing economy.

2 The Model

Consider a developing country where two firms, a local firm (Firm 1) and a multinational corporation (Firm 2), sell an identical product.(Firm 2 is called a multinational firm because we want to relate our discussion to the process patenting issue. Otherwise, Firm 2 could be any other firm.) The inverse demand function for the product is given by, $p = a - bx$, where p is the price and $x = \sum_i x_i$ $(i = 1,2)$ is the total quantity produced and sold in the market. Initially, we assume that the unit costs of production are identical and constant, c, for both firms. Further, assuming both firms behave as Cournot duopolists under full information, the profit function for firm i is,

$$\pi_i = x_i[a - b(x_i + x_j) - c], \quad (i \neq j = 1,2). \tag{1}$$

The equilibrium output of each firm is:

$$x_i(0) = \frac{(a-c)}{3b}, \quad (i = 1,2). \tag{2}$$

It follows that total output sold in the market is, $x(0) = 2(a-c)/3b$, and the profit of each firm is, $\pi_i(0) = (a-c)^2/9b$. We refer to this equilibrium as **E(0)**.

We assume that under complete information both firms use the equilibrium (Cournot-Nash) strategy. In the absence of complete information, the local firm (Firm 1) always sets its output at the level which maximizes its expected profit. If information on unit cost is asymmetric, the local firm does not adjust its output as a myopic profit maximizer. If it does so, the multinational, with unchanged unit cost, may drive the market to equilibrium, **E(2)** (the equilibrium under which both firms behave as if Firm 2 has been successful in reducing its cost), through bluffing. The local firm knows this. Hence, it maximizes expected profit given its belief. Therefore, the market may be driven to an equilibrium which is not Markov-perfect. The local firm revises its belief only when the multinational's output-signal convinces the local firm that such a signal cannot be a result of bluffing. We assume that the firms adjust their outputs in the following sequence. Firm 2 (the multinational) announces that, because of technological invention and efficiency gains, it has been able to reduce its cost from c to $c-\delta$ (which could be stated in percentage terms), in an effort to force Firm 1 to revise its output level so that Firm 2 will gain from the revision. In response, Firm 1 sets its output first and Firm 2 responds with its best reply. Then Firm 1 moves again and the game goes on until equilibrium is reached. In other words, the firms are engaged in an infinitely repeated sequential game. Each period consists of a move from the local firm and a response from the multinational. The reader should note the difference from a repeated leadership game, where the multinational always plays the role of a follower maximizing its current profit. The multinational does not always maximize its current profit given the output of the local firm. It can adopt a bluffing output signal with a hope of gaining in the long-run (avoiding a return to equilibrium **E(0)**). This is a follower-follower Cournot game with possible false output signalling. A *long-run equilibrium* is a state which is repeated indefinitely given the parameters of the game. We define the *transitory equilibrium* as the configuration (x_1, x_2) which represents the first moves of both the firms under asymmetric cost information.

Suppose, there is a possibility that the multinational may have actually invented a new technique of production reducing its unit cost to $c-\delta$. However, the local firm is not sure whether the multinational has actually improved the process of production or not. If the period of patenting seems to be too short for Firm 2, even if it has actually been able to reduce the cost, it may not be willing to take a patent of the new technology because of the fear that the local firm will simply copy it after a short period. When its true unit cost is c, for a given x_i, the reaction function of Firm 2 is,

$$x_2 = \frac{(a-c-bx_1)}{2b}. \tag{3}$$

When the multinational is successful in reducing the unit cost, its reaction function is,

$$x_2' = \frac{(a-c+\delta-bx_1)}{2b}. \tag{4}$$

Suppose the local firm places a probability λ on the event that the multinational has been able to reduce the unit cost. Its expected profit for a given x_1 is,

$$E(\pi_1) = (1-\lambda)[\{a-b(x_1+x_2)-c\}x_1] + \lambda[\{a-b(x_1+x_2')-c+\delta\}x_1]. \tag{5}$$

Since Firm 1 maximizes its expected profit under asymmetric information, it produces,

$$x_1(1) = \frac{(a-c)}{3b} - \frac{\lambda\delta}{3b}. \tag{6}$$

Consequently, Firm 2 produces either,

$$x_2(1) = \frac{(a-c)}{3b} + \frac{\lambda\delta}{6b}, \tag{7}$$

in the absence of any technological improvement, or,

$$x_2'(1) = \frac{(a-c+2\delta)}{3b} - \frac{(1-\lambda)\delta}{6b}. \tag{8}$$

Either $(x_1(1), x_2(1))$ or $(x_1(1), x'_2(1))$ represents equilibrium **E(1)**. Gibbons (1992) discusses Eqs.(6) - (8) as one-period solutions of the Cournot game with asymmetric cost information. We shall show that in an infinitely repeated Cournot game Eqs.(6) and (7) yield only a transitory (one-period) equilibrium not a long-run equilibrium. Only under restrictive conditions may Eqs.(6) and (8) yield a long-run equilibrium.

Proposition 1. *In the infinitely repeated Cournot game with imperfect information the outcome $(x_1(1), x_2(1))$ can only be a transitory equilibrium which represents only the initial response of Firm 2.*

Proof. Clearly, Firm 1 is producing less than what it would produce in equilibrium **E(0)**. Firm 2 has a larger share of the market because of cost uncertainty. If the multinational sets x_2 according to Eq.(7), the total output sold in the market is smaller in amount and the price is higher. The local firm's profit goes down in spite of the higher price, because of a drop in its output. The amount of its loss is, $(\lambda\delta/18b)(a - c + \lambda\delta)$. On the other hand, the multinational's profit increases because of a higher price and larger output. However, if the multinational sets x_2 according to Eq.(7), the local firm realizes that Firm 2 has not been able to reduce its cost, so in the next period it sets $\lambda = 0$ and the Nash equilibrium is restored as a full (complete) information equilibrium and is given by Eq.(2). □

Instead of myopic profit maximization, the multinational, not successful in reducing unit cost, can take a long-term view. For example, it may be tempted to give a false signal by pretending that it has actually reduced the cost of production by δ and set $x_2 = x'_2(1)$, provided it is profitable for the firm in the long-run. Obviously, in case the multinational has actually been able to reduce its cost it would also signal it by setting $x_2 = x'_2$. For the sake of brevity, Firm 2 will be referred to as F_2^* if it has been able to reduce the unit cost. Otherwise, if Firm 2 has not been able to reduce the unit cost, we shall refer to it as F_2.

When the local firm is convinced that the multinational has actually been able to reduce the unit cost and is not bluffing, the local firm and F_2^* would move to the long-run equilibrium

E(2) where the values of x_1 , x_2 and x are given by:

$$\begin{aligned} x_1(2) &= \frac{(a-c)}{3b} - \frac{\delta}{3b}, \\ x_2(2) &= \frac{(a-c)}{3b} + \frac{2\delta}{3b}, \\ x(2) = x_1(2) + x_2(2) &= \frac{2(a-c)}{3b} + \frac{\delta}{3b}. \end{aligned} \tag{9}$$

F_2, giving a false output signal, will move to **E(2)** only if it is profitable for it to do so. We shall analyse this case in detail. In the long-run, the multinational sells a larger amount of output in the market. However, since the total output is larger but the price is lower, F_2 may actually suffer a loss in profit in the long-run equilibrium **E(2)**) by giving a false signal.

Lemma 1. *F_2 may have a long-run incentive to falsely signal that it has achieved a cost reduction by setting output at $x_2'(1)$ if and only if $\delta < (a-c)/2$ and no incentive to give a false signal if $\delta \geq (a-c)/2$ in the long-run.*

Proof. Under a false signal, the change in the long-run profit of F_2 from equilibrium **E(0)** is: $[\delta(a-c) - 2\delta^2]/9b$. If it is positive, F_2 has a long-run reason to give a false signal by setting its output to $x_2'(1)$. This implies that F_2 may give a false signal if, $\delta < (a-c)/2$. On the other hand, if $\delta \geq (a-c)/2$, F_2 will have no incentive to give a false signal in the long-run. □

This is important for the local firm. It knows that if $\delta \geq (a-c)/2$, the multinational's output response is not a bluff in the long-run. The next proposition further strengthens the result.

Proposition 2. *If $\delta \geq (a-c)/2$, F_2 has no incentive to give a false signal either in the long-run or in the short-run. Therefore, in this case, either **E(0)** or **E(2)** will prevail as the long-run equilibrium.*

Proof. By Lemma 1, F_2 does not have any long-run incentive to keep on giving a false signal and move to **E(2)**. When it has not been able to reduce the cost, it also loses by giving a false output signal in **E(1)**. It is easy to check, $x_2'(1) < x_2(2)$. However, total output $x_1(1) + x_2'(1) >$

$x(2)$. This implies that in **E(1)** the price is lower than the price in **E(2)**. Consequently the unit profit is lower in **E(1)** than in **E(2)**. Since the output of Firm 2 is also lower in **E(1)**, the total profit of Firm 2 must also be lower in comparison with **E(2)**. By Lemma 1, it is not profitable for F_2 to keep on giving a false output signal and move to **E(2)**. Therefore, it is also not profitable for F_2, to give a false signal and move to **E(1)**. In this case, F_2 does not gain either in the short-run or in the long-run by giving a false output signal. Note, though F_2^* incurs a lower profit in **E(1)** than in **E(2)**, in both equilibria F_2^* enjoys higher profits than in **E(0)**. When $\delta \geq (a-c)/2$ we have an *information generated separated* equilibrium. If x_1 and x_2 are determined by Eqs.(6) and (7) in the transitory period, then the long-run equilibrium **E(0)** prevails with F_1 and F_2. If x_1 and x_2 are determined by Eqs.(6) and (8) in the transitory period, in the next move, Firm 1 will set $\lambda = 1$ and the firms, F_1 and F_2^* will move to the long-run equilibrium **E(2)**. $\square$

When the envisaged reduction in unit cost is small, $\delta < (a-c)/2$, Firm 1 knows that F_2 will bluff (i.e., produce $x_2'(1)$), in order to persuade it that F_2 has actually been able to reduce the unit cost, so that in the long-run equilibrium **E(2)** prevails. Of course, F_2^* will also produce the quantity $x_2'(1)$. We have the possibility for a case of *pooled equilibrium* due to lack of information. From the response of the multinational, the local firm cannot be sure whether the multinational has actually been able to cut the unit cost. Hence, the local firm's output will continue to be determined by Eq.(6). This creates a problem for F_2^*. It will continue responding with the output level $x_2'(1)$, but the local firm cannot be made to believe that it has actually reduced the unit cost. For F_2^*, the configuration

$$\begin{aligned} x_1(1) &= \frac{(a-c)}{3b} - \frac{\lambda\delta}{3b}, \\ x_2'(1) &= \frac{a-c+2\delta}{3b} - \frac{[(1-\lambda]\delta}{6b}. \end{aligned} \tag{10}$$

is the Nash equilibrium under asymmetric information when $\delta < (a-c)/2$.

The local firm's profit level is lower (by the amount $\delta^2/9b$) in the full information Nash equilibrium **E(2)** characterized by Eq.(9) as compared to the Nash equilibrium under asymmetric information given by Eq.(10). In this case, the value of information is negative for the local firm (Sakai, 1985). Therefore, unless F_1 is fully convinced that Firm 2 has been able to reduce its cost, it will produce $x_1(1)$ rather than $x_1(2)$. On the other hand, F_2^* is better off, if F_1 produces $x_1(2)$ rather than $x_1(1)$. If it could convince the local firm about the truth of the reduction in cost without revealing the details of the technological change, it would do so. Without a long-term process patenting accepted, F_2^* prefers not to reveal the details of the change in the process of production and keep the process as a secret.

Let us further explore the case when $\delta < (a-c)/2$. It may seem possible for both firms to be in a long-run equilibrium **E(1)** where the Firm 2, which has actually not been able to reduce its cost, bluffs its way in.

Proposition 3. *If F_2 produces $x_2'(1)$, its profit is greater than what it would earn in the full information equilibrium **E(0)**, if and only if,*

$$\delta < \frac{[4\lambda(a-c)]}{9-\lambda^2}. \tag{11}$$

Therefore, if Eq.(11) holds, the multinational will always bluff and the long-run equilibrium is $(x_1(1), x_2'(1))$.

Proof. It is easy to check that in this case $\delta < (a-c)/2$. We have to show that $\pi_2'(1) > \pi_2(0)$ for F_2, if Eq.(11) holds. When $\delta < (a-c)/2$, Firm 1 knows that Firm 2 may give a false signal to lure it to equilibrium **E(2)**. Therefore, its response is $x_1(1)$, though the output of Firm 2 is $x_2'(1)$. The total output is, $x'(1) = 2(a-c)/3 + \delta/(2b) + \lambda\delta/(6b)$ and the price is $p'(1) = a - 2(a-c)/3 - \delta/2 + \lambda\delta/6$. The change in the profit from **E(0)** is:

$$\pi_2'(1) - \pi_2(0) = x_2'(1)(p'(1) - c) - \frac{(a-c)^2}{9b} = \frac{\lambda\delta(a-c)}{9b} - \frac{\delta^2}{4b} + \frac{\lambda^2\delta^2}{36b}.$$

For the change of profit to be positive, the above expression must be positive which requires, $4\lambda(a-c) > \delta(9-\lambda^2)$ implying $\delta < [4\lambda(a-c)]/(9-\lambda^2)$. In this case, F_2 will always bluff and the long-run equilibrium is $(x_1(1), x_2'(1))$. In this case, the F_1 is unable to determine whether

Firm 2 has been able to reduce the unit cost or not. □

The case when $(a-c)/2 > \delta \geq [4\lambda(a-c)]/(9-\lambda^2)$ is interesting. F_2 knows that F_1 will always produce $x_1(1)$ because of the possibility of false signalling. Hence it will like to play $x_2(1)$ in the first round for temporary gain and then both players should move back to the initial equilibrium **E(0)**.

In Tables 1 and 2, the results have been summarized. The value of δ can fall in three different ranges. The upper limit of the first range is $\delta_1 = [4\lambda(a-c)]/(9-\lambda^2)$. The upper limit of the second range is $\delta_2 = (a-c)/2$. The upper limit of δ in the third range is c.

Insert Tables 1& 2 Here

In the context of a pooling equilibrium due to the lack of sufficient information, F_2^* may wish to send output signal to the local firm that it is has actually been able to reduce unit cost and is not bluffing. The next proposition states that no such signalling mechanism is available to F_2^* in the context of an infinitely repetitive game without time discounting.

Proposition 4. *When $\delta_1 \leq \delta < \delta_2$, no output signalling mechanism is available to F_2^* to convince F_1 that it has been able to reduce the unit cost, in the context of a repetitive game without time discounting. In this case, both the transitory and the long-run equilibrium for (F_1, F_2) is $(x_1(1), x_2'(1))$.*

Proof. The local firm wishes to be in the equilibrium $(x_1(1), x_2'(1))$ rather than in equilibrium **E(2)**, unless it is convinced that the multinational has, indeed, been able to reduce the unit cost. Suppose, there exists an output signalling profile $x_2(t)$ for F_2^*, which after a period T, persuades the local firm to accept equilibrium **E(2)**. Then it is also preferred to equilibrium **E(0)** by F_2, since the sum of finite gains in profit over the remaining infinite time horizon is greater than the sum of finite losses over a finite period. Knowing this, F_1 will always play $x_1(1)$ and the pooling equilibrium $(x_1(1), x_2'(1))$ will prevail. □

When both firms are discounting profits and maximising the sum of discounted profits which is common knowledge, it is possible for F_2^* to convince F_1 that it has actually reduced the unit cost.

Proposition 5. *Consider the case $\delta_1 \leq \delta < \delta_2$. If both firms are maximizing the sum of discounted profits with α as the discounting factor which is common knowledge, then it is possible for F_2^* to find an output signalling profile $x_2(t)$ which, after a period T, must convince the local firm that the multinational has successfully reduced the unit cost.*

Proof. If F_2^* always produces $x_2'(1)$ in the absence of any discounting of profits, the profit difference from equilibrium **E(0)** is positive in each period. For F_2, the profit difference is negative. Let us define T as the minimum time horizon when the discounted sum of difference in profits over the infinite horizon for F_2 is negative if at T, both firms move to equilibrium **E(2)**. Clearly, when F_2^* is producing $x_2'(1)$ for T periods, it is recognized that the multinational has successfully reduced its cost and both firms move to equilibrium **E(2)**. The signalling strategy mentioned here is myopic. It is not necessarily the optimal output signalling strategy. The optimal signalling strategy $x_2(t)$, when $\delta_1 \leq \delta < \delta_2$, is given by:

$$\max_{x_2(t)} \sum_{t=0}^{T} \alpha^t \pi_2^*(x_1(t), x_2(t)) + \sum_{t=T}^{\infty} \alpha^t \pi_2^*(x_1(2), x_2(2)), \quad 0 < \alpha < 1,$$
$$T = \min\{\tau | \sum_{t=0}^{\tau} \alpha^t \Delta\pi_2(x_1(1), x_2(t)) + \sum_{t=\tau}^{\infty} \alpha^t \Delta\pi_2(x_1(2), x_2(2)) \leq 0\}.$$

$\pi_2^*(.)$ is the profit in each period if the multinational is F_2^*. Similarly, π_2 is the profit per period if the multinational F_2. $\Delta\pi_2(.)$ denotes the deviation of π_2 from its value in the equilibrium **E(0)**. Given the output signal $x_2(t)$, T is the period, when F_1 will agree to switch to equilibrium **E(2)**. However it remains true that the multinational will be better off if it could convince the local firm in the first round that it has, indeed, been able to reduce the unit cost. □

In the case of $0 < \delta < \delta_1$, the story is more complicated and a profitable output signalling profile may not exist. In this case, whether the multinational is successful or not (F_2 or F_2^*), it enjoys a higher profit at $x_2'(1)$ in comparison with equilibrium **E(0)**. F_2^* obviously enjoys a higher profit than F_2. In order to convince the local firm of its success, F_2^* may choose a level of output $x_2 > x_2'(1)$ which will yield a negative profit difference to F_2 but for F_2^* the profit difference is non-negative, though F_2^* will be worse off in comparison with the output configuration $(x_1(1), x_2'(1))$. In case of time discounting, for F_2 there must exist a T after which, if it continues with the same output level, the discounted sum of the profit differences will be negative if it were F_2. Therefore, if F_2^* carries on producing x_2 beyond period T, it should give the local firm a clear signal that the multinational has been successful in reducing its costs and both firms will move to the full information equilibrium **E(2)**. However, up to period T, F_2^* is sacrificing a part of its profit (with respect to the configuration $(x_1(1), x_2'(1))$ in order to convince the local firm that it has been able to reduce unit cost. If the cost is greater than the gain from the ultimate move to equilibrium **E(2)**, then the long-run equilibrium under asymmetric cost information, $(x_1(1), x_2'(1))$ will prevail. The multinational will have no incentive to signal its success. If the cost is less than the gain, signalling will take place and ultimately both firms will move to the full information equilibrium **E(2)**. Obviously, the parameters of the system, δ and α play a crucial role in determining whether it is profitable for the multinational to try to achieve equilibrium **E(2)** through output signalling.

3 Firms' Strategic Behaviour and Process Patenting

The issue of patenting was put in the agenda for an intense international debate in the Uruguay round (1986-94) initiated by the Dunkel Draft (Chowdhry & Aggarwal, 1994). Patents can be granted on the final product as well as on the production process. Some countries usually allowed patents on the production process but seldom on the final product in certain industries, unless the product is uniquely related to the process of production. It was feared that patenting of the final product would stifle competition and act as a barrier to improvements in the production technology and to a reduction in the cost of production.

In the presence of competitors, a reduction in cost is reflected in a reduction of price and an increase in consumer surplus. This issue was important in the context of medicine. For example, it was argued by the local pharmaceutical companies in India, by inventing new processes of production, were able to reduce the cost of some drugs significantly. This was important for the vast multitude of poverty stricken people in India. However, in the absence of strict enforcement of patenting, the Indian pharmaceutical market was also full of counterfeit products which were dangerous to the health of the patients. Moreover, it is more likely that in the competition for cost reduction, the multinationals with a much higher R&D spending capability should be able to reduce the cost more effectively than relatively under-financed local pharmaceutical companies.

During the debate on the Dunkel draft, the local pharmaceutical firms in India argued that without competition, the multinationals would not invest in R&D to reduce the cost of production. However, the case for process patenting was far less controversial. The argument was about the length of the period for process patenting. The patenting period also varies between countries. Many developing countries have a short patenting period. In the 1970 Act, India reduced the patenting period from 16 to 14 years in general. For medicine it was reduced to 7 years. There was no product patent available for chemicals. The Dunkel Draft proposed a patent period of 20 years for both the process and the product directly obtained through the process. This was finally accepted in the Final Act of 1994 with some important exceptions. USA (with the tacit consent of the G-7 countries) was widely accused of twisting the arms of the developing countries to accept what virtually was the Dunkel Draft. The main argument in favour of extending the period of patent to 20 years was that unless sufficient protection is granted under the intellectual property rights (IPR), the multinationals would not be interested in investing large sums of money in R&D to invent new products or to improve the existing technology of production.

In some areas like medicine, bio-technology (Acharya, 1991) and communications, it is absolutely important to keep up the momentum for progress. This cannot be disputed. However, there is an aspect of process patenting which has not been well-recognised in the literature. Quite often the technology of production cannot be identified from the final product. Such products are produced by different producers, with different technologies of production, without obtaining relevant patents. Quite often secrecy is preferred to patenting (Lunn, 1987). If patents are granted only for a short period, it is not desirable to obtain patents for processes and disclose the technology of production. It is better to keep it as a secret. In such cases the information on the cost of production or the state of technology is asymmetric. However, it has a cost to the firm using more efficient technology (the multinational in our case). If the long-run market equilibrium in the duopoly model is $(x_1(1), x_2'(1))$, the multinational, successful in reducing its unit cost, earns less than what it could earn in the full information equilibrium **E(2)**. With profit discounting, even when the firms ultimately move to equilibrium **E(2)**, Firm 2 may have earned a low profit for a substantial period in its effort to signal its success.

With a long period for process patenting, the multinational patents its process to convince its rival of its relative production efficiency. But this information has a negative value to the local producer. The market will move to equilibrium **E(2)**, where the local producer is worse off and the multinational is better off. Thus, an extension of the period of process patenting may interfere with the long-run equilibrium given the strategic behaviour of the firms. It is expected that the multinationals with large scale investments in R&D employ, in general, more efficient technologies. Therefore, a substantial extension of the period of process patenting under the TRIP agreement in the Final Act of 1994, gives a strategic advantage to the multinationals operating in the underdeveloped countries.

An important question is whether the consumers in the developing country are better off in the full information equilibrium.

Proposition 6. *Both the consumers and the local producer are worse off at* ***E(2)*** *in comparison with* ***E(1)*** *implying a negative overall effect of the full information equilibrium.*

Proof. We have already noted that the local producer is worse off at **E(2)**. The consumers in the market are better off in the full information equilibrium if:

$$x_1(2) + x_2(2) > x_1(1) + x_2'(1) \quad \Rightarrow \quad \frac{\delta}{3b} > \frac{\delta}{2b} - \frac{\lambda\delta}{6b} \quad \Rightarrow \quad 2 > 3 - \lambda.$$

Since $0 < \lambda < 1$, this is not possible. Hence, under the full information equilibrium, the total output produced is less and the price of the product is higher in comparison with the long-run equilibrium $(x_1(1), x_2'(1))$. The consumers in the market are better off in the equilibrium under asymmetric information than in the equilibrium with full information. In the full information equilibrium, not only do the local producers earn a smaller profit, the consumers' surplus is also smaller because of a smaller amount of product sold in the duopoly market with a higher price. $\square$

4 Concluding Remarks

Whether an extension of the patenting period benefits developing countries in the long-run is a controversial issue. Some people believe that an extension of the period of patents will encourage local firms to invest more in R&D and increase their efficiency. There are others who believe that it will hurt the local firms. Bureaucracy had always been a problem for taking patents. The cost of taking patents on products in developed countries, particularly in the USA is prohibitive for the firms in developing countries. Time will tell whether the fears of the developing countries are well founded or not. This paper only deals with the effect of new information, generated by the extension of the patenting period of processes, on the producers and consumers in a developing economy. We have chosen the Cournot model with asymmetric information as the backbone of our analysis. Bonanno & Haworth (1998) compare the relative suitability of the Cournot and Bertrand models for analysing the behaviour of patenting by firms. They concluded that the Cournot model is a better model for analysing process patenting whereas the Bertrand model is more suitable for the analysis of product patenting. Finally, there is a question of economic justice involved in our discussion. Some may argue that it is fair that the full information equilibrium should prevail and firms should get what they deserve. On the other hand, some would argue that a deal which makes a third world country worse off is not a fair deal. The Final Act of the Uruguay round sought a balance. It will take some time for the trading world to realize its full implications

Table 1: The Transitory Equilibrium

Firms	$0 < \delta < \delta_1$	$\delta_1 \leq \delta < \delta_2$	$\delta_2 \leq \delta \leq c$
(F_1, F_2)	$x_1(1), x_2'(1)$	$x_1(1), x_2(1)$	$x_1(1), x_2(1)$
(F_1, F_2^*)	$x_1(1), x_2'(1)$	$x_1(1), x_2'(1)$	$x_1(1), x_2'(1)$

Table 2: The Long-Run Equilibrium

Firms	$0 < \delta < \delta_1$	$\delta_1 \leq \delta < \delta_2$	$\delta_2 \leq \delta \leq c$
(F_1, F_2)	$x_1(1), x_2'(1)$	$x_1(0), x_2(0)$	$x_1(0), x_2(0)$
(F_1, F_2^*)	$x_1(1), x_2'(1)$	$x_1(1), x_2'(1)$	$x_1(2), x_2(2)$

F_1: Local Firm; F_2: Multinational with unit cost, c; F_2^*: Multinational with unit cost, $c - \delta$; $\delta_1 = \frac{[4\lambda(a-c)]}{9-\lambda^2}$; $\delta_2 = \frac{(a-c)}{2}$.

References

ACHARYA, R. 1991. Patenting of Biotechnology: GATT and the Erosion of World's Biodiversity. *Journal of World Trade*, 71–87.

BAGCHI, A.K., BANERJEE, P., & BHATTACHARYA, U.K. 1984. Indian Patents Act and its Relation to Technological Development in India: A Preliminary Investigation. *Journal of World Trade*, **19**, 287–304.

BONANNO, G., & HAWORTH, B. 1998. Intensity of Competition and the Choice between Product and Process Innovation. *International Journal of Industrial Organization*, **16**, 495–510.

CHOWDHRY, N.K., & AGGARWAL, J.C. 1994. *Dunkel Proposals (Vol. II): The Final Act 1994 - Significance for India and the World Trade*. Delhi: Shipra Publications.

DEOLALIKAR, A.B., & RÖLLER, L-H. 1989. Patenting by Manufacturing Firms in India: Its Production and Impact. *Journal of Industrial Economics*, **37**, 303–314.

GAL-OR, E. 1988. The Advantages of Imprecise Information. *Rand Journal of Economics*, **19**, 266–275.

GIBBONS, R. 1992. *A Primer in Game Theory*. New York: Harvester Wheatsheaf.

LUNN, J. 1987. An Empirical Analysis of Process and Product Patenting. *Applied Economics*, **19**, 743–751.

MIRMAN, L.J., SAMUELSON, L., & URBANO, A. 1993. Duopoly Signal Jamming. *Economic Theory*, **3**, 129–149.

MIRMAN, L.J., SAMUELSON, L., & SCHLEE, E.E. 1994. Strategic Information Manipulation in Duopolies. *Journal of Economic Theory*, **62**, 363–384.

PENROSE, E. 1973. International Patenting and Less-Developed Countries. *Economic Journal*, **83**, 768–786.

PONSSARD, J-P. 1976. On the Concept of the Value of Information in Competitive Situations. *Management Science*, **22**, 739–747.

PONSSARD, J-P. 1979. The Strategic Role of Information on the Demand Function in an Oligopolistic Market. *Management Science*, **25**, 243–250.

SAKAI, Y. 1985. The Value of Information in a Simple Duopoly Model. *Journal of Economic Theory*, **36**, 36–54.