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PUBLIC BASIC RESEARCH AND DIFFUSION OF RESEARCH BENEFITS

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Public Basic Research and Diffusion of Research Benefits

Abstract

The paper examine the economic impact of pricing and access to basic research IP. The analysis uses a Sallop circle model of a monopolistically competitive industry to examine the applied research output and firm entry. Under plausible conditions basic research IP spillovers will create rents for the applied research sector, which are dissipated through socially excess firm entry. Charging a price or restricting access to basic research IP could enhance social welfare.

Keywords: Pricing, intellectual property, downstream effects, basic research, monopolistic competition, rent dissipation, toll goods

Public Basic Research and Diffusion of Research Benefits

1.0 Introduction

Research is increasingly seen as an essential tool for economic development (Jorgenson and Stiroh 2000). This link, which is at the heart of endogenous growth theory (Romer 1990), has become widely accepted. For most OECD governments innovation strategy involves creating stronger intellectual property rights to stimulate private innovation combined with strategic investments in public research. In recognition of the potential for public research investment to crowd out private research and the difficulty in creating private incentives for basic research, some public funding has been shifted from applied research toward basic research. Therefore, the management of basic research output is increasing in importance.

In Canada and the United States public institutions are encouraged to facilitate commercialization of their IP, in many instances they are encouraged to act like private firms by pricing research output with the objective of generating additional research funds. The US 1980 Bayh–Dole Act (Sec.200-212, ch. 18, title 35 of the U.S. Code) allows and encourages US public universities to protect and charge for IP from federally funded research. In Canada, new federal government resources have recently been invested to strengthen the commercialization capacity of universities and government research organizations. The overall affect of these policies is that virtually all large public research organizations in North America have established offices with a function of managing the commercialization of IP.

Despite the growing consensus of the need to appropriately manage the commercialization of IP; a divergent range IP management strategies are employed in public institutions in North America. In Canada, a 2005 Statistics Canada survey of Canadian universities found that 75% of University IP license agreements with private firms were exclusive in nature (Smyth and Gray 2006). This practice is common among US institutions as well (Thursby and Thursby 2002, 2003, Jensen and Thursby 2001). At the same time, many research discoveries continue to be placed in the public domain through publication, while other discoveries are routinely licensed to multiple users on a royalty for use basis. The management of IP continues to evolve as public institutions strive to act in the public interest by finding the best policies to facilitate revenue generation, *freedom to operate*, and commercialization. The assessment of management impacts is inherently complex given the non-rival and often non-excludible nature of research output.[1]

Without IP enforcement, the output from research is both non-rival, non-excludable and therefore can be classified as a public good. Samuelson (1954, 1958) discussed the economic nature of public goods by offering examples of television broadcasting and lighthouses. He showed that given the non-rival nature of these goods and in the absence of other distortions, economic surplus is maximized when the price is set equal to the zero marginal cost (Samuelson 1954, 1958, 1964). The public dissemination of IP creates research spillovers, which are often an important source of productivity enhancement (e.g., Griliches 1992, Adams 1999, Alston and Pardey 1999).

With IP, enforcement research output becomes non-rival (excludable) toll good, which can also be provided by the private sector. However, given the zero marginal cost the technology can only be profitably produced in a non-competitive market where price is greater than marginal cost and at least as high as average cost (Fulton 1997, Lesser 1998, Fulton and Giannakas 2001, Schimmelpfinnig et al. 2004). In the case of exclusive

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[1] Non rival nature of research output means that one can use the technology created from R&D over and over again without depletion; while non excludable means that the inventor does not have the ability to exclude others from using, reproducing or selling the new technology or product created from R&D investment.

ownership, the IP has a monopoly over the use of the technology and can price to maximize revenue (Moschini and Lapan 1997). While this price behavior can provide private incentive to do the research, it also leads to social inefficient monopoly pricing. The pricing of IP also effects the distribution of the gains from research (e.g., Lindner 1993, Perrin 1994, Fulton and Keyowski 1999, Malla and Gray 2003, 2005). The negotiation of the rights to use IP can also become difficult and expensive; especially when a research product embodies many pieces of IP (e.g., Falcon and Fowler 2002, Kowalski et. al 2002, Binenbaum et. al 2003). The resulting *freedom to operate* can create the tragedy of the anticommons (e.g., Heller and Eisenberg 1998, Buchanan and Yoon 2000). Thus, while the enforcement of IP creates incentives for research it at the same time creates a number of complex issues.

The basic research IP differs from applied research IP in many important ways. Evenson and Kislev (1976) introduced the notion of basic research spillovers and showed that the outputs of basic research (i.e., scientific knowledge) can improve the productivity of applied research and many later studies use this notion (e.g., Lee 1982, 1985, Kortum 1997). Diamond (1999) and Robson (1993) empirically examined the crowding effects of basic research.[2] Scotchmer (1991) shows that basic research or initial innovation could facilitate later innovation by increasing its social value, reducing the research cost, or accelerating its development. Hence, the first innovator needs to be compensated for the externality or spillover that provides to the second innovator, while enough profit must be left for the second innovator so that they will invest if investment is efficient. Scotchmer (1991, p.35)

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[2] A related body of economic research examines the crowding effects of public research investment on private research investment. Some studies argue that publicly funded research competes for scarce resources and therefore could "crowd out" privately funded research (Roberts 1984, Bergstrom et al. 1986, and David and Hall 2000), while others show that public expenditure could cause a "crowding in" of private research expenditure(e.g., Khanna et al. 1995, Khanna and Sandler 1996). David, Hall and Toole (1999) provided a recent survey of the available empirical evidence and found that the results were inconclusive in terms of the direction and the magnitude of the relationship between public and private research expenditure.

also argues, “Incentives with licensing are defective mainly because firms negotiate after all costs have been sunk and patents have been issued.” This problem is exacerbated by the challenge in developing ex ante contracts for basic research, where results are particularly difficult to anticipate.

The inherently upstream nature of basic research IP can affect the incidence of management strategies. Unlike applied research where the users of the knowledge can be the final consumer or competitive industries, the same does not apply to basic research. In the case of basic research, the downstream firms are doing applied research are producing a toll goods and therefore are non-competitive by nature. The distortion created by non-competitive applied research means that an analysis of basic research IP management must take place in a “second best” framework. As the Lipsey and Lancaster “theory of the second-best” (1956) suggests that the elimination of one distortion does not necessarily result in a Pareto improvement as long as another distortion exists.

The objective of this paper is to examine some of the downstream incentive and distributional effects created by alternative pricing for public basic research discoveries. We begin by modeling the behavior of an imperfectly competitive private R&D sector to examine the pricing and research activities of private industry, over a range of potential spillovers and strategies pricing behavior. This modeling framework is then used to examine the optimal number of firms in the industry and will reveal that under Bertrand-Nash pricing behavior, the free entry results in an excessive number of firms relative to welfare maximizing number of firms. This result is consistent with the notion that restricted access to public basic research could be welfare enhancing. The framework we developed sheds light on issues related to the pricing and management of basic research discoveries that have become important in today's research environment.

The paper is organized into four sections. Section 2 contains the analytical framework to model private incentives and the equilibrium outcomes in the applied research industry. Section 3 examines the equilibrium number of firms, compares this to the welfare maximizing number, and describes how the restricted access to basic research IP could improve social welfare. Section 4 contains the conclusions and discussion of policy implications.

2.0 The Market Equilibrium for the Applied Research Sector

A game theory approach is used to analytically examine the behavior of the applied research sector. A partial-equilibrium imperfectly competitive framework, with differentiated products and heterogeneous users is developed; which also allows for complete and incomplete IP and a number of research spillovers among the public and private firms.

The analytical model was developed using a specific example of the agricultural biotech industry. The equilibrium research and pricing decisions in the industry are modeled in a two-stage game. Each of N research firms invest in applied research to improve their horizontally differentiated crop variety that will sell to downstream grain producers with heterogeneous land. In the first stage, each private firm decides on the quantity of applied research, which is used to create an improved variety with a specific yield. Given a yield outcome, each research firm chooses the price it will charge for its variety in the second stage. Grain producers who own heterogeneous land, who are also price takers in their output market, consider the prices and yields of the varieties and choose which variety to purchase on the basis of net returns. The equilibrium outcome for the model is solved using backward induction (Gibbons 1992).

2.1 Producers' Demand for Varieties

Finding the market equilibrium for the model begins by deriving the demand for the applied research output (e.g., the crop varieties). There are *N* applied research firms each selling a specific variety type to farmers with differential land attributes. For numerical convenience, we adopt the Salop circle model (Salop 1979, Ireland 1987) of imperfect competition. The land attribute is assumed to be uniformly distributed around a unit circle, with each variety type best suited to some location (equidistant apart) on the unit circle. Each arbitrarily small farm (*i*) has land with a quality attribute of ψ_i (e.g., soil quality, weed infestation, clay content). Each firm competes with a rival on each side. ie. firm *A* competing with firm *B* and firm *C* for market share.[3] Specifically, firm *A* is competing with firm *B*'s variety on one margin, and firm *A* is competing with firm *C*'s variety on the other margin.

Producers in the neighborhood of firm *A* can choose to purchase variety *A* from firm *A*, variety *B* from firm *B*, or variety *C* from firm *C*, for each type of land depending which variety produces the highest net returns. The objective of each producer is to maximize profit. The profit for growing variety A is shown in equation 1. A farmer with land quality ψ_i will be just indifferent to growing variety *A* vs. *B* when equation 2 holds.

$$\text{(1)} \qquad \pi_i = sp[y^A - \tau\frac{1}{N}\psi_i]z_i - z_i w^A$$

$$\text{(2)} \qquad sp[y^A - \tau\frac{1}{N}\psi_i]z_i - z_i w^A = sp[y^B - \tau(\frac{1}{N} - \frac{1}{N}\psi_i)]z_i - z_i w^B$$

where:

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[3] We model a horizontal product differentiation given that all products/varieties are ideal for some consumers/producers (Ireland 1987).

z_i = the area seeded by producer i
w^A = the price of seed of variety A
w^B = the price of seed of variety B
p = the price of output
ψ_i = the land characteristic of producer i, in the interval A B or A C ranging from 0 to 1.
τ = the change in yield associated with a unit change in the differential attribute, or degree of product differentiation
$y^A - \tau \frac{1}{N}\psi_i$ = the yield of variety A for producer of characteristic ψ_i
$y^B - \tau(\frac{1}{N} - \frac{1}{N}\psi_i)$ = the yield of variety B for producer of characteristic ψ_i

The parameter s is added to account for the different degrees of excludability of research benefits. When s is less than one, producers' opportunity cost of not purchasing the variety from the breeding firm is lower than its value because they have the opportunity to obtain the seed in other ways (such as purchasing from neighbors in the "brown bag" market or retaining seed from crop grown in previous years), which was the typical case for most non-hybrid crops until recently.

The proportion of area grown with variety A or C is symmetric to the proportion of area grown with variety A or B (or equation 1 and 2).

The value of $\hat{\psi}^{A,B}$ - which is the land quality of the producer who is indifferent between varieties A or B, or the market share of firm A in the interval AB that is $\frac{1}{N}$ long - can be computed mathematically as:

$$(3) \qquad N\left[\frac{sp(y^A - y^B) - w^A + w^B}{2\tau sp}\right] + \frac{1}{2} = \hat{\psi}^{A,B}$$

The value of $\hat{\psi}^{A,C}$ which is the market share of firm A in the interval AC ($\frac{1}{N}$ long) is given by:

$$(4) \qquad N\left[\frac{sp(y^A - y^C) - w^A + w^C}{2\tau sp}\right] + \frac{1}{2} = \hat{\psi}^{A,C}$$

The sum of $\hat{\psi}^{A,B}$ and $\hat{\psi}^{A,C}$ is equal to the total market share of variety *A*, or given the land density of one, the total quantity of variety *A* demanded. Similarly, the total quantity demanded, or the demand curve for variety *B* and variety *C* could be derived. Given these demand curves, the firms independently set profit-maximizing prices as described below.

2.2 Second Stage: Pricing of the Variety

The optimal pricing by firms selling varieties *A*, *B*, and *C* can be derived given the estimated producers' demand for those varieties. We assume that the firms operate in a single period and pick a price where the marginal revenue of the residual demand facing each firm from the sale of their variety is equal to the marginal cost of marketing and reproducing the seed. The profit-maximizing objective function of firm *A* is

$$(5) \qquad Max\, \Pi^A = \frac{1}{N}(\hat{\psi}^{A,B} + \hat{\psi}^{A,C})(w^A - L)\text{, or,}$$

$$(6) \qquad \left[\frac{sp(2y^A - y^B - y^C) - 2w^A + w^B + w^C}{2\tau sp} + \frac{1}{N}\right]\left[w^A - L\right]$$

where *L* is equal to marginal cost of marketing and reproducing of the seed.

The first-order condition (FOC) for this maximization is:

$$(7)\ \frac{\partial \Pi^A}{\partial w^A} = \left[\frac{sp(2y^A - y^B - y^C) - 2w^A + w^B + w^C}{2\tau sp} + \frac{1}{N}\right] + \left[\frac{-2}{2\tau sp} + \frac{\phi}{2\tau sp} + \frac{\phi}{2\tau sp}\right]\left[w^A - L\right] = 0$$

where ϕ *is* the conjectural variation $\left(\frac{\partial w^i}{\partial w^j} = \phi\right)$ takes the value of 1 in a case of cartel/monopoly, ϕ=0 in Nash/oligopoly, and ϕ=-1 in perfect competition.

Solving for seed price w^A, the best-response function of firm *A* can be computed. At the Nash equilibrium, the price charged by firms *A* is equal to w^{A*}, or:

$$(8)\qquad w^{A*} = \frac{sp(2y^A - y^B - y^C)}{5-2\phi} + \frac{\tau sp}{N(1-\phi)} + L$$

The price charged by firm *B* (w^{B*}) and *C* (w^C) are symmetric to w^{A*}:

$$(9)\qquad w^{B*} = \frac{sp(2y^B - y^C - y^A)}{5-2\phi} + \frac{\tau sp}{N(1-\phi)} + L$$

$$(10)\qquad w^{C*} = \frac{sp(2y^C - y^A - y^B)}{5-2\phi} + \frac{\tau sp}{N(1-\phi)} + L$$

Having determined the Nash pricing for firm *A*, *B*, and *C,* the equilibrium market share for variety *A* as a function of yields can be estimated by substituting the optimal pricing w^{A*}, w^{B*}, and w^{A*} for $\hat{\psi}^{i,j}$, which gives:

$$(11)\qquad \psi^{A,B*} = N\left[\frac{(y^A - y^B) - \phi(y^A - y^B)}{(5-2\phi)\tau}\right] + \frac{1}{2} \text{ or } \psi^{A,B*} = \frac{N(1-\phi)(y^A - y^B)}{(5-2\phi)\tau} + \frac{1}{2}$$

$$(12)\qquad \psi^{A,C*} = N\left[\frac{(y^A - y^C) - \phi(y^A - y^C)}{(5-2\phi)\tau}\right] + \frac{1}{2} \text{ or } \psi^{A,C*} = \frac{N(1-\phi)(y^A - y^C)}{(5-2\phi)\tau} + \frac{1}{2}$$

2.3 First Stage: Optimal Yield

The optimal research investment for firm *A*, *B*, and *C* is derived given the producers' demand for the varieties and the optimal pricing of the varieties by the firms. The profits of firm *A* are a function of price (w^A) and quantity sold (ψ_i), the distribution costs (*L*), and the cost of research (*c*) which is assumed to be a quadratic function of yield (*y*) of each variety, or:

$$(13)\qquad Max\,\Pi^A = \frac{1}{N}(\psi^{A,B*} + \psi^{A,C*})(w^{A*} - L) - \frac{1}{2}y^2 c$$

Substituting the equilibrium values for prices and market share, the objective function becomes:

(14)

$$\Pi^A = \left\{ \frac{1}{N}\left[N\frac{(y^A - y^B) - \phi(y^A - y^B)}{(5-2\phi)\tau} + \frac{1}{2}\right] + \frac{1}{N}\left[N\frac{(y^A - y^C) - \phi(y^A - y^C)}{(5-2\phi)\tau} + \frac{1}{2}\right]\right\} * \left\{\left[\frac{sp(2y^A - y^B - y^C)}{5-2\phi} + \frac{\tau sp}{N(1-\phi)} + L\right] - L\right\} - \frac{1}{2}\left(y^A\right)^2 c$$

Rearranging the terms in the above equation results in profits equal to:

(15)

$$\left[\frac{(2y^A - y^B - y^C) - \phi(2y^A - y^B - y^C)}{(5-2\phi)\tau} + \frac{1}{N}\right]\left[\frac{sp(2y^A - y^B - y^C)}{5-2\phi} + \frac{\tau sp}{N(1-\phi)}\right] - \frac{1}{2}\left(y^A\right)^2 c$$

The FOC for the maximum with respect to the amount of research for firm *A* is:

(16)
$$\frac{\partial \Pi^A}{\partial y^A} = \frac{(2-2\phi) + 2k(\phi-1)}{(5-2\phi)\tau}\left[\frac{sp(2y^A - y^B - y^C)}{5-2\phi} + \frac{\tau sp}{N(1-\phi)}\right] + \frac{2sp(1-k)}{5-2\phi}\left[\frac{(2y^A - y^B - y^C) - \phi(2y^A - y^B - y^C)}{(5-2\phi)\phi} + \frac{1}{N}\right] - cy^A = 0$$

where $\frac{\partial y^J}{\partial y^i} = k$, k takes values from 0 to 1 ($0 \le k \le 1$), when k=0 there are no spillovers, while when k=1 complete spillovers.

At the symmetric equilibrium, the FOC for firm *A* collapses to:

(17) $\frac{(2-2\phi) + 2k(\phi-1)}{(5-2\phi)\tau}\frac{\tau sp}{N(1-\phi)} + \frac{2sp(1-k)}{5-2\phi}\frac{1}{N} - cy = 0$, or:

(18) $$cy = \frac{2sp(1-\phi) + 2ksp(\phi-1) + (2-2\phi)sp + 2spk(\phi-1)}{(5-2\phi)N(1-\phi)}$$

Solving for the optimal yield target gives:

(19) $$y^* = \frac{4sp(1-k)}{(5-2\phi)Nc}$$

Based on equation (19), that shows the optimal applied research investment or expenditure (yield improvement), y^*, it could be inferred that:

- An increase in output price, *p*, will increase the private R&D investment.
- An increase in excludability of IP, *s*, will increase the private R&D investment.
- An increase in applied research spillovers, *k*; will reduce the private R&D investment and yields.
- An increase in the cost of research, *c*; will decrease the R&D output.
- An increase in the number of firms in the industry, *N,* will decrease the R&D investment per firm and yield.
- An increase in price collusion, ϕ, will increase the R&D investment.

3.0 Firm Entry and the Optimal Number of Firms

In section 2, the derived industry production and pricing behavior assuming there were *N* firms in the industry evenly dispersed in product space around the unit circle. With free entry firms entering the industry as long as expected profits are positive. If rents are high, many firms will enter the industry until the profits are driven to zero. In a toll good industry each firm must incur a fixed cost to operate.

3.1 The Market Equilibrium- Zero profit number of firms

The monopolistically competitive number of firms *N*, can be derived by substituting the optimal applied research investment (equation 19), *y**, and pricing behavior into the private firm's profit function (equation 13) and well as accounting for fixed cost per firm for entry, *F***,** which is:

$$(20) \qquad \Pi^A = \frac{1}{N}\frac{\tau sp}{N(1-\phi)} - \frac{1}{2}y^2 c - F = \frac{1}{N}\frac{\tau sp}{N(1-\phi)} - \frac{1}{2}\left(\frac{4p(1-k)}{(5-2\phi)Nc}\right)^2 c - F = 0$$

Solving for *N*:

$$(21) \qquad N_P{}^* = \left[\frac{\tau sp}{(1-\phi)F} - \frac{8s^2p^2(1-k)^2}{(5-2\phi)^2 Fc}\right]^{.5} \text{ or } N_P{}^* = \left[\frac{sp}{F}\left(\frac{\tau}{(1-\phi)} - \frac{8sp(1-k)^2}{(5-2\phi)^2 c}\right)\right]^{.5}$$

Based on equation (21) that shows the monopolistically competitive number of firms it could be stated that:

- An increase in product differentiation, τ , will increase the number of private firms and induce entry into the industry.
- An increase in excludability of IP, *s*, will increase the number of private firms and induce entry into the industry.
- An increase in output price, *p*, will increase the number of private firms and induce entry into the industry.
- An increase in applied research spillovers, *k*, will increase the number of private firms and induce entry into the industry.
- An increase in the cost of research, *c*, will decrease the number of private firms and deter entry into the industry.
- An increase in the cost of basic research (the fixed cost per firm for entry**)**, *F,* will decrease the number of private firms and deter entry into the industry.

The theoretical results and propositions were derived in a stylized model within the agricultural biotech industry. While we derive these results for a specific industry structure, the general incentives to invest in variety development and the propositions are likely to exist over a wide range of market structures, where firms operate in an imperfectly competitive market structure, where firms can increase both the price and the quantity for their product through research that improves product quality.

3.2 The socially optimal number of firms

The objective of a social planner is to maximize total economic surplus. Given a fixed output price, it is assumed that there is no downstream impact on consumer welfare. The economic surplus is made up of the producer surplus of applied research firms who breed varieties, and the growers/producers who purchase the varieties. The impacts on the growers' producer surplus or the welfare effects are measured in the associated input market, without considering the other input markets.

The sum of the market producer surplus of farmers who own the unit circle of land defined as:

$$(22)\ PS^F = py^* + \frac{1}{4}\frac{p\tau}{N} - w^* = \frac{1}{4}\frac{p\tau}{N} + p\left\lfloor \frac{4sp(k-1)}{(5-2\phi)Nc} \right\rfloor - \frac{\tau sp}{N(1-\phi)} - L$$

The producer surplus of breeding firm A is determined by:

$$(23)\qquad PS^{B} = (w^{*} - L) - \frac{1}{2}Ncy^{2} - FN = \frac{\tau sp}{N(1-\phi)} - \frac{(4sp(k-1))^{2}}{2(5-2\phi)^{2}Nc} - FN$$

Hence, the social welfare function can be defined as:

(24) $SW = PS^{F} + PS^{B}$ or,

$$(25)\ SW = \frac{1}{4}\frac{p\tau}{N} + p\left[\frac{4sp(1-k)}{(5-2\phi)Nc}\right] - L - \frac{(4sp(1-k))^{2}}{2(5-2\phi)^{2}Nc} - FN$$

The first order condition for the socially optimal number of firms

$$(26)\quad \frac{\partial SW}{\partial N} = -\frac{1}{4}\frac{sp\tau}{N^{2}} - \frac{4sp^{2}(1-k)}{(5-2\phi)N^{2}c} + \frac{\left[4sp(1-k)\right]^{2}}{(5-2\phi)^{2}N^{2}c} - F = 0$$

Solving the above equation for the social optimal N_{S}^{*}, result in:

$$(27)\qquad N_{s}^{*} = \left[\frac{sp}{F}\left(\frac{8sp((1-k))^{2} - 4p(1-k)(5-2\phi)}{(5-2\phi)^{2}c} - \frac{\tau}{4}\right)\right]^{.5}$$

The number of social optimal firms similar to the private optimal number, are strictly increasing functions of the product differentiation, τ, output price, *p,* price collusion, ϕ. While it is a strictly decreasing function of the marginal cost of research, *c,* and the fixed cost *F*. For example, the more collusive the firms are in pricing (ϕ = 1)*,* the socially optimal number of firms increases.

3.3 The Implications for Managing Basic Research IP

An important policy question is whether the access to basic research IP can facilitate or deter additional entry of firms in applied research[4]. From equation 27, the socially optimal number

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[4] This is particularly relevant given the predominance of exclusive licensing agreements which by their nature limit the number of downstream firms using the basic research.

of firms is equal to $N_s^* = \left[\frac{sp}{F}\left(\frac{8sp((1-k))^2 - 4p(1-k)(5-2\phi)}{(5-2\phi)^2 c} - \frac{\tau}{4}\right)\right]^{.5}$. While from equation 21, the number of firms that will exist in a monopolistically competitive equilibrium $N_P{}^*$ is equal to $N_P{}^* = \left[\frac{sp}{F}\left(\frac{\tau}{(1-\phi)} - \frac{8sp(1-k)^2}{(5-2\phi)^2 c}\right)\right]^{.5}$. A direct comparison of the firm numbers is difficult without values for each of the parameters.

When applied research property rights are complete such that *k*=0and *s* =1, and firms set to prices in a Bertrand-Nash way such that ϕ=0, then $N_S{}^* = \left[\frac{25c\tau p - 16p^2}{100Fc}\right]^{.5}$ and $N_P{}^* = \left[\frac{100c\tau p - 32p^2}{100Fc}\right]^{.5}$.

Taking the ratio of the socially to privately optimal number of firms, results in:

(28)

$$\frac{N_S^*}{N_P^*} = \frac{\left[\dfrac{25c\tau p - 16p^2}{100Fc}\right]^{.5}}{\left[\dfrac{100c\tau p - 32p^2}{100Fc}\right]^{.5}} = \sqrt{\frac{25c\tau p - 16p^2}{2\left(50c\tau p - 16p^2\right)}} = \sqrt{\frac{25c\tau p - 16p^2}{50c\tau p + 2\left(25c\tau p - 16p^2\right)}} =$$

(29) $$\frac{N_S^*}{N_P^*} = \sqrt{\frac{1}{\dfrac{50c\tau p}{\left(25c\tau p - 16p^2\right)} + 2}} < 1.$$

Given that $25c\tau p - 16p^2$ is greater than zero then the ratio is strictly less than one. This implies that the socially optimal number of firms is less than the number of firms in the monopolistically competitive equilibrium or $N_S{}^* < N_P{}^*$.

The result that $N_S{}^* < N_P{}^*$ suggests that profit motivated free entry into a monopolistically competitive industry is excessive from the social welfare perspective. This is not surprising given the applied research industry produces a toll good where average cost decreases with each firm's output. Competition reduces each rivals firm size and increases average costs. In this sense firm entry in the industry dissipates the rent that would be enjoyed by a fewer number of firms. If a breakthrough in basic research occurs, which lowers the applied research costs or demand increase for applied research output such that rents accrue to those in the applied research industry, firm entry will reduce these rents and will cease only when rents have been dissipated.

Restricting access to basic research IP can increase social welfare. Given that firm entry in the applied research industry can reduce social welfare and dissipate rents, restricting the applied research industry access to basic research IP could plausibly be welfare improving. The basic research IP could be managed in a number of ways to restrict entry and to reduce rent dissipation in the downstream-applied research industry. The effectiveness of each instrument will be affected by; industry structure, the nature of the downstream demand, research spillovers, and other research incentives for the sector.

The public sector could curtail the downstream by charging fixed price on access to the basic research IP, ie. x$ per crop variety. This charge would be less than or equal the additional downstream applied rents, which would reduce spillover induced entry into the industry. Establishing the appropriate price could be difficult, given that negotiations would have to take place prior to the applied research. At this point, the value of the basic research IP would be very uncertain particularly for the public agency pricing the IP.

The public research firms could charge a per unit royalty on the sale of the applied research. This management practice would reduce some of the risk and information asymmetry associated with prior lump sum negotiation and could serve to reduce the rents for the downstream-applied research firms and reduce entry. Unfortunately, this policy would also add an additional marginal cost to the sale of the applied research output and would move the variety prices further from the zero marginal cost.

The most obvious way to prevent excess entry and rent dissipation is to auction off limited access to the basic research IP. Issuing an exclusive agreement is an extreme where the applied research firm is granted a monopoly for the use of the basic research IP. This commonly used management strategy is simple and prevents excess entry, but can have the side effect of creating a downstream monopoly.

4.0 Summary and Policy Conclusions

Research spillovers and in particular, basic research spillovers, can have important implications on downstream industry structure, research intensity, innovation and rent distribution. The optimal public research investment and whether public research tends to "crowd in" or "crowd out" private research has been the focus of academics and policy makers, while questions like, how access to the public innovation is granted and at what price does the exchange take place, were generally overlooked.

To examine this issue a two-stage game theoretical model was developed to examine the incentives that exist within a monopolistically competitive applied research sector using the example of crop research. Horizontal product differentiation is assumed to exist in the sector, where product attributes and buyer preferences are distributed in a unit circle. We consider a range of incomplete IP, inter-firm research spillovers, and conjectural variation. The socially optimal number of firms is derived and outcomes are compared to the monopolistically competitive outcome.

The monopolistically competitive number of private firms is an increasing function of product differentiation, inter-firm research spillovers, downstream IP, collusion in pricing, and the price of output; and is a decreasing function of the cost of research, and fixed cost. Research output per firm increases with the output price, excludability of IP, and applied research spillovers, while firm output decreases with the cost of research, the number of firms in the industry, and price collusion.

A comparison to the social optimum reveals that under plausible assumptions the monopolistically equilibrium results in an excess number of firms in the industry. This means that basic research spillovers can result in the expenditure of additional resources to capture the flow of the under priced goods, which in turn, results in over investment in research using activities and rent dissipation. When basic research spillovers can create rents for applied research, then giving away or under pricing an asset, will result in dissipation and reduction in social welfare. On the other hand, granting more restricted access to basic research results; such as an exclusive licensing, could under some conditions, create a welfare improvement over unpriced public release of the IP. The results strongly suggest that research spillovers, how access to the public innovation is granted, is a very important economic issue and has policy relevance

The study systematically analyzes the private research investment and firm entry or industry structure in today's research industry. The results support and extend the work of Evenson and Kislev (1976) that examine the effect of basic research spillovers on the productivity of applied research; the work of Mansfield (1980), Link (1981), Griliches (1986) who found that basic research is a more important determinant of productivity; and Malla and Gray (2005) that examine the private research investment incentives and incidence. The framework developed in this study presents a more general industry case (e.g., *N* firms, circle model, horizontal product differentiation) and allows for a systematic examination of a number of factors that determine private research behavior such as various research spillovers, collusion in pricing, and different degrees of patent protection etc.

The main contribution of the study is a better understanding of the economic impacts of under pricing basic research or basic research spillovers. Basic research spillovers affect research intensity and firm's entry or industry structure. The results suggest that unrestricted access to public research discoveries can lead to excessive firm entry and rent dissipation if there are economies of size downstream. Anecdotal empirical evidence such as private industry proliferation in US soybeans, corn, cotton and Canadian canola; the flood of private expenditure and number of varieties; and the decreasing rates of return (e.g., canola) are consistent with the results of this study and suggest the need to address the pricing of public intellectual property rights. Zero price open access may not the optimal solution.

This study identifies an important issue for the management of basic research IP, but leaves a great many more questions unanswered. Is there a rule of thumb for the optimal number of firms? How should firms be selected? Are there options for IP trading as payment? How inferior is a simple royalty structure? Are exclusive license arrangements socially efficient? Under what conditions? More work is needed.

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