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Biodiversity, intellectual property rights and north-south trade

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Abstract

In this paper, we examine how biodiversity levels are affected by different regimes of trade-related intellectual property rights (IPRs) in a two-way trade framework where the North and South import and export to each other`s market. This approach incorporates domestic consumption (and hence consumer surplus) into the welfare maximization problem of the Southern government in a three-stage game under alternative IPR regimes. We find that for achieving a maximal level of biodiversity and socially optimal welfare in the South, the Southern government should protect farmers` rights. Further, we find that the Southern government has economic incentives to acknowledge international patents and protect biodiversity even in the absence of farmers''s rights.

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1. Introduction

There have been many international agreements regarding the protection of intellectual property rights over the years. One important area that was not initially addressed, but has recently been discussed, is the protection of biological organisms. In particular the Trade-Related Intellectual Property Rights (TRIPS) Agreement of GATT included an option to protect animals and plants in Article 27 (3) b. One type of life form that is particularly relevant to intellectual property right (IPR) protection is genetically engineered plants and animals. These life forms require substantial research and development (R&D) and many argue that the discoveries need to be protected in order to continue to provide an incentive to engage in this kind of research.

However, a problem can arise from the fact that many firms go to other countries and access the flora and fauna present there to obtain ideas or information on how to better produce genetically engineered plants and animals. In this case firms can go to areas where native farmers have cultivated different seed varieties for many years. This type of cultivation is typically present in developing countries. The cultivation is predicated on free exchange of knowledge between farmers, and when firms go to draw on this knowledge they can do so without cost (Brush, 1992, p. 1619; Wood, 1998). This can cause a conflict between the farmers and the firms when there is no compensation for the farmers. There is also the problem that biodiversity can be decreased as farmers will not be able to draw on the knowledge of the firms for free due to patent protection if Article 27 (3) b of TRIPS is enforced. One concern is that this would lead to a decrease in the variety of plants worldwide (Shand, 1997; Swanson and Göschl, 2000).[1]

In their recent contribution, Droege and Soete (2001) was the first to formally incorporate the important notion of farmers' rights into a model of strategic trade policy under imperfect competition. Specifically, the authors examined the environmental issues of biological diversity by developing a North-South model where a Northern firm and a Southern firm export crop seeds to a third market. In their analysis, two different regimes of IPR protection are discussed. The first of these are international patent protections that would be similar to those enforced under Article 27 (3) b of TRIPS. The second regime discussed is farmers' rights. In this regime the native farmers are compensated for the knowledge that previously had been disseminated for free. Enforcement of these farmers' rights could potentially alleviate the aforementioned problems of knowledge exchange without compensation. Under farmers' rights, Northern firms would be required to pay fees to the Southern government in exchange for the knowledge gained from the Southern farmers.

As noted by Droege and Soete, the present policy (which is similar to only implementing patent protections, but not farmers' rights) would lead to perhaps the very outcome it is designed to prevent; the elimination or decline of biodiversity in the world. While providing interesting insight to the problem of protecting biodiversity, there are some limitations to their model setup. First, because of the assumption that the North and South export a commodity to a third market, there is no inclusion of domestic consumption (and hence consumer surplus) in the welfare maximization decision of the Southern government. In fact, Droege and Soete call for

[1] Swanson and Göschl (2000) examine how intellectual property rights affect the incentive to conserve plant genetic diversity. They indicate that the current IPR system puts more emphasis on the retail end of the plant breeding industry and less on plant genetic diversity. As a consequence, the IPR system is insufficient in increasing the availability of genetic resources for the plant breeding industry.

extensions of their analysis that incorporate consumer surplus. Consumer surplus could have very important implications for the Southern government as increasing the overall level of production of just the Northern firm could have positive implications for the national welfare of the South. This could lead to higher biodiversity levels for certain situations and could also lead to a positive level of biodiversity for the case of international patent protection with or without implementation of farmers' rights. Second, by structuring the analysis with the Northern and Southern firms importing and exporting to each other's market, a more realistic picture of North-South trade can be gained. It is in response to these limitations that the present model is proposed.

We will show that the incorporation of consumer surplus into the welfare maximization problem of the Southern government in a two-way trade model significantly alters the equilibrium outcome under alternative IPR protection policies. The major results of our North-South trade model are as follows: (i) Taking into account the domestic consumption of a commodity such as crop seeds, the Southern government has an economic incentive to acknowledge international patents despite the absence of farmers' rights. (ii) Total payoff of the Northern firm is maximized when only its technological patent is protected. (iii) Under free trade without any forms of IPR regimes, biodiversity will not be maintained by the Southern government. All of these results stand in contrast with the findings of Droege and Soete.–(iv) The maximal levels of biodiversity and social welfare in the South are achieved by implementing farmers' rights and leaving international patents unprotected. This result is in line with the findings of Droege and Soete.

The remainder of the paper is organized as follows. Section 2 presents a simple North-South trade model to analyze environmental issues on biodiversity and IPRs. We examine the economic incentives for the Southern government to implement two independent property rights regimes (technological patents and farmers' rights), and the resulting effect on competition and biodiversity. In Section 3, we analyze the equilibrium outcomes of alternative IPR regimes and discuss policy implications of the North-South model. Section 4 concludes.

2. The Analytical Framework

2.1 Biodiversity and IPRs in North-South Trade

In order to address issues on North-South trade and further consider consumer welfare in the South, a model that has the Southern and Northern firms importing and exporting to each other's market is needed. The natural choice of an analytical framework for North-South trade is a stylized two-way trade model (Brander, 1981; Brander and Krugman, 1983). We wish to determine the conditions under which the Southern government has an incentive to maintain biodiversity in its country and to implement the protection of patents at the international level.

As in Droege and Soete (2001), we consider a three-stage game with two firms where there is one firm located in the North and one firm located in the South. These firms produce a homogeneous good, crop seeds, x_i, $i=1,2$ for the Northern firm, and y_i, $i=1,2$ for Southern firm. For these firms there are two cost-reducing components, a and *b*. The term a denotes the level of *technology* that is invested in by the Northern firm and reduces the cost of producing the seeds. Only the Northern firm is able to undertake R&D investment that lowers the cost of technology as captured by a decrease in a.[2] If patent protection for the Northern technology is chosen by the Southern government, then the Northern firm will choose l, a licensing fee, that the Southern firm must pay in order to use the technology a in its production of seeds. The term b denotes the level of *biodiversity* that is maintained by the Southern government. It too reduces the cost of producing seeds for the two firms.

Additionally, there is a Southern government that can choose between two different types of IPR protection: (i) the enforcement of the Northern firm's patents in developing a commercial technology and (ii) the enforcement of Southern farmers' rights in preserving the traditional cultivation methods (Droege and Soete, 2001). Specifically, it can implement patent protection for the Northern technology a. If the Southern government chooses to protect the patent on the Northern technology, then the parameter θ_1 takes on a value of 1. If international patent protection is not chosen by the Southern government, then θ_1 takes on a value of 0. The Southern government also chooses whether or not it will implement *farmers' rights* in its country. If then Southern government chooses to implement farmers' rights, then the parameter θ_2 takes on a value of 1. In this case of farmers' rights protection, the Northern firm must pay a royalty of r in order to access biodiversity b, but the Southern firm will still have free access to it. If farmers' rights are not protected then both firms will have free access to the level of b that is chosen by the Southern government. In this case θ_2 takes on a value of 0.

The structure of the three-stage game is as follows. In stage one, the Southern government chooses a property right regime combination, θ_1 and θ_2, and determines its socially welfare-maximizing levels of royalties r and biodiversity b. In the second stage, the Northern firm chooses its optimal level of technology a and it chooses licensing fee l if international patent protection is implemented by the Southern government. In the third and last stage of the three-stage game, the Northern and Southern firms adopt a Cournot strategy and simultaneously determine their outputs for both the domestic and foreign markets. The game is solved by backward induction.

2.2 The Sub-game Perfect Nash Equilibrium of the Three-Stage Game

We begin with the third stage where each profit-maximizing firm decides on outputs for sales in its domestic market and for export to the rival firm's market. In this stage the property rights regimes, $\{\theta_i, r, l\}$, the level of technology, a, the size of the pool of knowledge, b, are taken as given by the two firms. The Northern firm chooses output for the Northern market (x_1) and output for the Southern market (x_2). The Southern firm chooses output for the Northern market (y_1) and output for the Southern market (y_2). For analytical simplicity, we assume that the market demand facing each firm in the North is $p_1 = \alpha - D_1$, where $D_1 = x_1 + y_1$. Likewise, the market demand facing each firm in the South is $p_2 = \alpha - D_2$, where $D_2 = x_2 + y_2$. These assumptions imply that the size of each market is the same. Both firms face a (constant) marginal cost of production, c. For our analysis we assume that $c < \alpha < (372/137)c$. This

[2] We follow Chin and Grossman (1990), Žigic (1998) and Droege and Soete (2001) to assume that only the Northern firm is able to undertake R&D investment in technology.

assumption ensures first that markets are sufficiently large. It also ensures that marginal costs are not too low which helps to make investments in cost-reducing technologies necessary. Both firms also face a constant transport cost of k for the output that is exported to the foreign market.

The cost function for each firm becomes:

$$TC_1 = [c-(\delta a+b)+\theta_2 r]x_1 + [c-(\delta a+b)+\theta_2 r + k]x_2 - F \text{ ,} \tag{1}$$

$$TC_2 = [c-(\delta a+b)+\theta_1 l]y_2 + [c-(\delta a+b)+\theta_1 l + k]y_1 - F \text{ ,} \tag{2}$$

where δ reflects the degree of effectiveness of the cost-reducing technology relative to biodiversity, and F is fixed cost. As can be seen from (1) and (2), the intellectual property rights regimes chosen by the Southern government affect the cost functions of each firm. If patent protection is selected by the Southern government, then the Southern firm must pay licensing fee l to the Northern firm to use technology a. If the Southern government does not choose patent protection, then the Southern firm does not need to pay licensing fee l to the Northern firm to use technology a. If the Southern government chooses farmers' rights then the Northern firm must pay royalty r to the Southern government in order to access the pool of knowledge b. No matter the IPR regime chosen by the Southern government the Southern firm will always be able to use the pool of knowledge b.

The firms maximize their profits by choosing output for each market. Variable profits (excluding fixed costs) of the Northern and Southern firms are given respectively as

$$\pi_1 = [\alpha-(x_1+y_1)]x_1 + [\alpha-(x_2+y_2)]x_2 - [c-(\delta a+b)+\theta_2 r]x_1 - [c-(\delta a+b)+\theta_2 r+k]x_2 \text{ ;} \tag{3}$$

$$\pi_2 = [\alpha-(x_2+y_2)]y_2 + [\alpha-(x_1+y_1)]y_1 - [c-(\delta a+b)+\theta_1 l]y_2 - [c-(\delta a+b)+\theta_1 l+k]y_1 . \tag{4}$$

Assuming that the transport cost of k is zero for analytical simplicity (and to match the analysis of Droege and Soete), we calculate the Nash equilibrium levels of outputs for each firm in each market as follows:

$$x_1^* = \frac{1}{3}(\delta a + b - c + \alpha + \theta_1 l - 2\theta_2 r) \text{ ,} \tag{5}$$

$$y_1^* = \frac{1}{3}(\delta a + b - c + \alpha - 2l\theta_1 + r\theta_2) \text{ ,} \tag{6}$$

$$x_2^* = \frac{1}{3}(\delta a + b - c + \alpha + \theta_1 l - 2\theta_2 r) \text{ ,} \tag{7}$$

$$y_2^* = \frac{1}{3}(\delta a + b - c + \alpha - 2l\theta_1 + r\theta_2). \tag{8}$$

As can be seen by looking at each firms' output function if b and a increase, then the output of each firm for each market increases. Also for the Northern firm, an increase in the royalty r decreases its output in each market and an increase in the licensing fee l increases its output in each market. The results for the Southern firm are the exact opposite of those for the Northern firm in terms of changes in the licensing fee and the royalty payment.

In the second stage of the game, the Northern firm chooses investment in technology a and the licensing fee l it will charge the Southern firm to use the technology. In this stage the Northern firm takes the IPR regime choices made by the Southern government as given. It also takes the pool of knowledge b and the royalty payment r as given as well. As mentioned in Droege and Soete, the licensing fee choice is contingent upon whether or not the Southern government chooses to implement international patent protection. The cost of investing in the cost-reducing technology a is assumed to be a^2.

Then Northern firm maximizes its payoff, denoted as G_1, by choosing a and l. The payoff function G_1 is comprised of the Northern firm's profits, the revenues from the licensing fee $l(y_1+y_2)$, and its cost of the technology, a^2. The maximization problem is:

$$\text{Max } G_1 = \pi_1 + \theta_1 l(y_1+y_2) - a^2, \tag{9}$$

where π_1 is given in (3). Substituting equations (5)-(9) into G_1, we derive the first-order conditions for the Northern firm as follows:

$$\frac{\partial G_1}{\partial a} = 9a - \delta(2a\delta + 2b - 2c + 2\alpha - 5\theta_1 l + 4\theta_2 r) = 0; \tag{10}$$

$$\frac{\partial G_1}{\partial l} = \theta_1(10\alpha + 10\delta a + 10b - 10c - 20\theta_1 l - 2\theta_2 r) = 0. \tag{11}$$

To keep the analysis as simple as possible and to obtain interior solutions, we set the value of the parameter δ to $1/2$ when comparing four alternative IPR regimes.

We first examine Case 1 in which international patents and farmers' rights are implemented by the Southern government, that is, $\theta_1 = \theta_2 = 1$. Using the FOCs in (10) and (11), we calculate the equilibrium values for a and l as follows:

$$a^* = \frac{2}{7}(\alpha + b - c - r); \tag{12}$$

$$l^* = \frac{2}{35}(10\alpha + 10b - 10c - 3r). \tag{13}$$

These equilibrium values indicate that an increase b increases both the equilibrium technology and licensing fee. Also, an increase in r decreases both the equilibrium technology and licensing fee.

If the Southern government chooses not to implement international patent protection then the licensing fee will be nonexistent. The technology chosen by the Northern firm is as follows:

$a^* = \frac{2}{7}(\alpha + b - c - r)$ if the Southern government implements farmers' rights;

$a^* = \frac{2}{7}(\alpha + b - c)$ if the Southern government does not implement farmers' rights.

This shows again that the larger b is, the larger the investment in technology by the Northern firm will be. Also, the larger r is the smaller a will be. For the case where farmers' rights are not implemented, a is the largest.

In the first stage of the three-stage game, the Southern government chooses the IPR regimes, as well as the level of biodiversity and the royalty the Northern firm must pay for accessing the pool of knowledge, in order to maximize the social welfare of the Southern country. The Southern government's welfare function is composed of the consumer surplus from consumption of the crop seeds, the profits of the Southern firm, and the revenue gained from the royalty fees paid by the Northern firm to gain access to the pool of knowledge maintained by the Southern government. That is, the Southern government's problem is to choose b and r that

$$\text{Max } W_2 = CS_2 + \pi_2 + \theta_2 r(x_1 + x_2) - b^2, \tag{14}$$

where $CS_2 = \int_0^{D_2} (\alpha - X)dX - p_2 D_2 = \frac{1}{2}(x_2 + y_2)^2$, π_2 is given by equation (4), and the firms' equilibrium outputs are given in (5)-(8).

Based on the FOCs for the Southern government: $\frac{\partial W_2}{\partial b} = 0$ and $\frac{\partial W_2}{\partial r} = 0$, we calculate the equilibrium levels of biodiversity and royalty per unit of output as follows:

$$b^* = 0.54(\alpha - c); \tag{15}$$

$$r^* = 0.62(\alpha - c). \tag{16}$$

Substituting the optimal values of b^* and r^* from (15) and (16) into (12) and (13), we calculate the optimal values of a^* and l^* in the second stage of the game:

$$a^* = \frac{1}{7}(2\alpha + 2b^* - 2c + 2r^*) = 0.26(\alpha - c); \tag{17}$$

$$l^* = \frac{2}{35}(10\alpha + 10b^* - 10c - 3r^*) = 0.77(\alpha - c). \tag{18}$$

Substituting equations (15)-(18) into equations (5)-(8), we determine equilibrium outputs by the firms. We further calculate the Northern firm's net payoff (variable profits net of R&D expenditures):

$$G_1^* = \pi_1^* + l_1^*(y_1^* + y_2^*) - (a^*)^2 = 0.64(\alpha - c)^2.$$

The Southern firm's profits as well as the South's consumer surplus and social welfare are calculated as follows:

$$\pi_2^* = 0.12(\alpha - c)^2;\ CS_2^* = \frac{1}{2}(x_2^* + y_2^*)^2 = 0.21(\alpha - c)^2;\ W_2^* = CS_2^* + \pi_2^* + r^*(x_1^* + x_2^*) = 0.54(\alpha - c)^2.$$

These results are recorded in Table 1.

Under the regime with double protection for both the Northern firm's technological patent and farmers' rights in the South (Case 1), we find that the Southern government's optimal level of biodiversity is strictly positive. This result is consistent with the finding of Droege and Soete that there is an incentive to maintain a positive level of biodiversity for the Southern government. To compare social welfare, it is necessary to determine the equilibrium outcomes of other IPR regimes.

3. Alternative IPR Regimes and Their Comparisons

Having developed the analytical framework of North-South trade in Section 2, we find that it is straightforward to examine alternative IPR regimes when $\theta_i (i = 1, 2)$ takes on a value of

0 or 1. Our previous assumption about the relative sizes of α and c are needed for Case 2 to ensure that markets exist and that we obtain an interior solution for this case. For Case 4 the optimal level of biodiversity is $(-3/217)(10\alpha + 41c)$. Therefore, as long as α and c are positive, the level of biodiversity for Case 4 will be 0. To save space, we summarize the equilibrium outcomes for the four different cases in Table 1.

For the regime under which the Southern government implement farmers' rights without enforcing international patents (Case 2), we have $\theta_1 = 0$ and $\theta_2 = 1$. In this case there is a substantial rent-shifting effect (in that there involves a transfer of income from a Northern firm to the Southern government). It is this case that provides both the maximal level of social welfare for the Southern government and ensures the highest level of biodiversity. These results confirm the analysis of Droege and Soete for the case of two-way trade. For this level of the analysis, the inclusion of consumer surplus does not affect the equilibrium chosen by the Southern government.

For the regime under which the Southern government enforces international patents and does not implement farmers' rights, we have $\theta_1 = 1$ and $\theta_2 = 0$ (Case 3 in Table 1). As discussed in Droege and Soete (2001), the strategic choice of the Northern firm is its R&D investment. For the Northern firm, its overall payoff (profits net of cost-reducing R&D expenditures) is highest when its technology patent is protected by the Southern government without implementing farmers' rights. The consequence is that the Northern firm becomes the only producer (i.e., a monopolist). To the Northern firm, the loss of licensing fees is more than offset by the reduction in paying royalties if there were farmers' rights. Interestingly enough, the Southern government in this case may still have an incentive to undertake investment in maintaining biodiversity. As illustrated in table 1, the equilibrium value of b is strictly positive. This finding runs counter to the model of Droege and Soete (2001), which shows that in this case biodiversity "will not be maintained by the Southern government" (p. 160).

For the regime under which the Southern government does not implement patent protection and farmers' rights, we have $\theta_1 = \theta_2 = 0$ (Case 3 in Table 1). This, in essence, is when there is free trade without any forms of government intervention. Unsurprisingly, this is the only case where the equilibrium level of biodiversity is 0. This points to the importance of implementing IPR protection, at least at some level, for achieving biodiversity. While various IPR protection regimes have varying outcomes, all are shown to be superior to free trade in terms of the level of biodiversity that is maintained by the Southern government. Interestingly, the level of social welfare for the South under free trade is higher than that in Case 3 (patent protection only). This finding lends credence to the idea of constraining the Southern government's choices in the interest of biodiversity (provided that farmers' rights are not an option).

Droege and Soete (2001) show that the Southern government favors only farmers' rights, and has no incentive to implement international patent protection. Quite contrary to this finding, we find that the Southern government may have an incentive to implement international patents even in the absence of farmers' rights.[3] The literature on trade-related intellectual properties (TRIPs) has examined Southern countries' incentives in the protection of international patents based on technological R&D. The condition for Southern protection of international patents is

[3] For our Case 3, we find that social welfare in the South is positive, whereas for our Case 3, Droege and Soete (2001) find that social welfare in the South is zero.

when the R&D investments are sufficiently productive to benefit Southern countries. (See, e.g., Chin and Grossman, 1990; Diwan and Rodrick, 1991; Deardorff, 1993).

Our study further shows that there is a dilemma for the Northern firm in terms of supporting farmers' rights in the South. The Northern firm's profits are the highest when only patents are enforced. But the Northern firm's profits are higher when both technological patents and farmers' rights are enforced compared to a situation where none of them are enforced. These findings contrast with those of Droege and Soete's. They find that the Northern firm's profits are highest for the case of patent protection and farmers' rights.

The importance of farmers' rights for the protection of biodiversity can be seen in the fact that farmers' rights are always biodiversity increasing. Regardless of the choice made as to whether or not to enforce international patents, biodiversity levels can be increased by implementing farmers' rights. This lends urgency to the idea that policymakers should be drafting agreements that provide for the implementation of farmers' rights.

4. Concluding Remarks

In this paper, we have presented a stylized model of North-South trade to analyze environmental issues concerning how biodiversity decline is affected by alternative IPRs enforced by the Southern government. Our model departs from the existing literature in some important aspects. Unlike Droege and Soete (2001), who assume that both the North and South export crop seeds to a third country, we consider a two-way trade framework where the North and South export crop seeds to each other's market. Second, our model further allows for consideration of consumer welfare when the Southern government chooses IPR regimes.

We find that the choice of the Southern government when maximizing Southern social welfare is to implement farmers' rights and to not protect international patents. This regime also provides for the highest levels of biodiversity maintained by the Southern government. We also find that the South's social welfare is positive for the cases of patent protection with or without farmers' rights. These finding indicate that the Southern government has an incentive to implement patent protection.

For the case of patent protection and no farmers' rights, the Southern government does have an incentive to maintain biodiversity at a positive level. This is particularly noteworthy as Droege and Soete did not find that the Southern government had any incentive to maintain biodiversity under this regime. It is also notable that this is the regime that currently has a provision under the TRIPS agreement of GATT. These results lend credibility to the idea that the inclusion of consumer surplus has important implications for the maintenance of biodiversity by the Southern government, and provides a different result than the existing literature on this subject, both in the economic arena and non-economic arena. Further analysis will provide insight into the regime that will actually be chosen by the Southern government and thus the level of biodiversity that will be maintained by the Southern government. If the welfare maximizing regime chosen by the Southern government is a regime where biodiversity is not maximal, then that could provide motivation to draft international agreements which constrain the choice of the Southern government if it is in the best interest of the world to have maximal biodiversity.

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Table 1: ***Equilibrium Results of Alternative IPR Regimes***

	Case 1 **Patents and FR** $(\theta_1 = \theta_2 = 1)$	Case 2 **No Patents but FR** $(\theta_1 = 0, \theta_2 = 1)$	Case 3 **Patents but no FR** $(\theta_1 = 1, \theta_2 = 0)$	Case 4 **No IPR protection** $(\theta_1 = 0, \theta_2 = 0)$
Technology (a)	$0.26(\alpha - c)$	$0.09(\alpha - c)$	$0.34(\alpha - c)$	$0.12(\alpha - c)$
Licensing fee (l)	$0.77(\alpha - c)$	0	$0.68(\alpha - c)$	0
Biodiversity (b)	$0.54(\alpha - c)$	$1.84(\alpha - c)$	$0.20(\alpha - c)$	0
Royalty fee (r)	$0.62(\alpha - c)$	$1.02(\alpha - c)$	0	0
Northern firm's net payoff (G_1)	$0.64(\alpha - c)^2$	$0.06(\alpha - c)^2$	$0.82(\alpha - c)^2$	$0.24(\alpha - c)^2$
Southern firm's profits (π_2)	$0.12(\alpha - c)^2$	$3.39(\alpha - c)^2$	0	$0.25(\alpha - c)^2$
Southern country's Consumer surplus (CS_2)	$0.21(\alpha - c)^2$	$1.25(\alpha - c)^2$	$0.23(\alpha - c)^2$	$0.25(\alpha - c)^2$
Southern country's social welfare (W_2)	$0.54(\alpha - c)^2$	$1.84(\alpha - c)^2$	$0.20(\alpha - c)^2$	$0.50(\alpha - c)^2$