Producer-Funded Innovation: R&D Spillovers across Levy Programs

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Abstract

Agricultural R&D investment is becoming an increasingly important policy issue as food prices push upwards and food security problems emerge. An important source of agricultural R&D funding is from producer check-offs, which are increasingly being used to fund applied agricultural research. Existing studies of producer-funded agricultural R&D indicate that there are high private and social rates of return to agricultural R&D investment by farmers, and thus that farmers are under investing in R&D. An important reason for under-investment of producer-funded R&D is the spillovers across levy programs – the research benefits of one particular crop can flow to other crops via spillovers. The spillovers across levy programs are particularly important in jurisdictions, such as Canada, where agricultural R&D activity has been organized on a commodity-by-commodity basis. This study developed a theoretical model to capture farmers R&D investment decisions by explicitly specifying spillovers across levy programs.

Keywords: Innovation, producer organizations, agricultural R&D, spillovers.

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Introduction

Agricultural research and development (R&D) investment is becoming an increasingly important policy issue as food prices push upwards and food security problems emerge [Alston, Beddow, and Pardey, 2009]. In Canada, an important source of agricultural R&D funding is producer check-off, which is increasingly used to finance applied research such as disease management, genetic improvement, and weed control. It is believed that producer check-off is a desirable way to fund agricultural R&D because to tax producers directly is more efficient than tax the general population [Alston, Freebairn, and James, 2003].

Among hundreds of existing studies of agricultural R&D, only a few have been done on producer-funded agricultural R&D. Existing studies of producer-funded R&D indicate that there are high private and social rates of return to agricultural R&D investment by farmers. For instance, [Scott et al., 2005] estimate the benefit/cost ratio for the Western Canadian Wheat producer check-off to be 4.4 to 1 (every one dollar check-off investment in R&D generates 4.4 dollars in increased producer surplus) and 12.4 to 1 for barley grower check-offs. [Gray et al., 2008] show that the benefit/cost ratio for the Saskatchewan Pulse Growers is 15.8 to 1, the internal rate of return (IRR) is 39.0 percent from 1984 to 2012; the benefit/cost ratio is 20.2 to 1 and the IRR is 39.5 per cent over the period 1984 to 2024.

These high returns indicate farmers are under investing in R&D. Given such high rates of return, a critical question is "Why do farmers not invest more money in agricultural R&D?" Are there any other factors that could affect farmers' decisions that are missing in the existing explanations? These are important questions and to answer them it is necessary to understand the factors that may affect farmers' decision-making process when it comes to R&D investment.

There are a number of explanations as to why farmer organizations would underinvest in R&D. These problems include the free-rider problem, the control problem, the heterogeneity problem, and the horizon problem (Olson [1971]; Cook [1995]; Alston and Fulton [2012]; Vitaliano [1983]). These problems emerge because of the individual incentives facing producers in a collective organization and because of the manner in which decisions are made within the organization.

Another important reason that has been missing in previous studies of producer-funded R&D is the spillovers across levy programs – the research benefits of one particular crop can flow to other crops via spillovers. A typical example of spillovers across levy programs is that wheat growers can benefit from the R&D activities conducted by pulse producers without undertaking the research costs. This kind of spillovers occur because pulse crops can fix nitrogen in the soil, improve land quality, and thus increase wheat productivity. Therefore, across-levy program spillovers can cause disincentives for pulse farmers to invest in R&D due to their incapability of capturing entire R&D benefits.

The spillovers across levy programs are particularly important in Canada, where agricultural R&D activity has been organized on a commodity-by-commodity basis. For instance, in western Canada, the wheat growers, the canola growers, the pulse growers, and the barley growers all run separate check-off systems and all make their R&D decisions independently of each other.

Research Objectives

The purpose of this paper is to examine how spillovers across levy programs impact farmers R&D investment decisions. More specifically, this research will develop a theoretical framework to capture farmers R&D investment decisions by explicitly specifying the spillover issue. The methodological framework developed to analyze this question is applied to the specific case of Canadian pulse and wheat industry, i.e., how spillovers from pulse production to wheat producers impact pulse farmers R&D investment decisions. The spillovers from pulse R&D to wheat production is defined as the change of producer surplus for wheat growers with respect to the change of pulse R&D investment.

Pulse crops are selected because Canada is the largest pulse exporter in the world market and more than 90 percent of Canadian pulses are produced in Saskatchewan (SPG Annual Report). R&D activities of pulse crops in Canada can be expected to have a significant impact on international trade and domestic and overseas consumers and producers. Furthermore, understanding how cross-levy spillovers impact farmers' decisions on producer-funded R&D will generate profound policy implications.

Research Methodology

The objective will be undertaken in the case of a large open economy by developing a dynamic product differentiation model given R&D benefits can take a considerable time to occur. On the production side, farmers are assumed to differentiate in returns they receive from farming and the difference stems from the different land quality they cultivate. The determination of the output supply of peas and wheat can be modelled as a two-stage sequential game with complete information. In stage one, the producer group determines the R&D investment, i.e., the check-off ratio. In stage 2, heterogeneous farmers determine the profit-maximizing output. The game is solved backwards. Moreover, the change of farmers' welfare caused by pulse R&D will be analyzed. The spillovers from pea R&D investment to wheat production will be defined as the change of welfare obtained by wheat producers from pulse R&D investment. Furthermore, the model considers the lags that occur between R&D investment and increases in the research benefits. This dynamic framework would be an extension of the traditional product differentiation model.

On the demand side, a vertical product differentiation model will be used under the assumption that pulses are potentially superior to wheat products because they provide a wide variety of health benefits such as high fiber, protein, and iron. They are low in fat and sodium, and cholesterol free (SPG Annual Report, 2009).

The Theoretical Model

Supply in Canada

On the production side, the model assumes that in Canada there is fixed amount of land L that can be allocated either to produce peas or wheat. The land is of heterogeneous quality, which is indexed on a continuum by the variable z. Under the assumption of fixed amount of farmland, z can be normalized to $z \in [0, 1]$. Farmers are assumed to differ in their land quality z and are uniformly distributed along [0, 1]. Under the assumption of fixed proportion, each farmer uses one unit land to produce one unit output. Moreover, an individual with a higher z has higher land quality.

The determination of the output supply of peas and wheat can be modelled as a two-stage sequential game with complete information. In stage one, the producer group determines the R&D investment, i.e., the check-off ratio. In stage 2, heterogeneous farmers determine the profit-maximizing output. The game is solved backwards. Moreover, the change of farmers' welfare caused by pulse R&D will be analyzed. The spillovers from pea R&D investment to wheat production will be defined as the change of welfare obtained by wheat producers from pulse R&D investment.

Stage 2: Determination of Optimal Output

As Alston et al. [2010] argue that the benefits of agricultural R&D may occur for as long as 50 years, with the maximum benefits occurring at approximately 25 years on average. Given the long period of time over which the benefits of R&D investment occur, a dynamic product differentiation model will be developed. As well, it is assumed that farmers rotate the crops once a year, i.e., farmers who grow peas in one particular year will grow wheat in the next year, and wheat growers will grow peas in the next year.

Period 1: Before Rotation (t=1)

As Figure 1 shows, a horizontal product differentiation model will be used in this setting. Farmers are assumed to differ in returns they receive from farming and the difference stems from the different land quality they cultivate. A producer with land quality of z at time period t has the following net-return function:

$$\pi_{pct} = p_{pt}(1 - l_p)y_p(z) - \gamma_p z + K_{pt} \qquad \text{per acre profit function for pea production} \tag{1a}$$

$$\pi_{wct} = (p_{wt} - \bar{l}_w)y_w(z) - f_{wt}(z) - \gamma_w z \qquad \text{per acre profit function for wheat production} \tag{1b}$$

where p_{pt} is the farm price for per unit output of peas net of all production costs, p_{wt} is the farm price of per unit output of wheat net of all production costs except fertilizer; l_p is the check-off ratio for peas collected on a percentage base, $\bar{l}_w$ is the per unit check-off of wheat; y_p is the yield of peas, and y_w is the yield of wheat.

It is indicated from equation (1b), the characteristic of pulses to fix nitrogen to improve the yield and lower the fertilizer costs of wheat – the spillover – is captured in the per acre

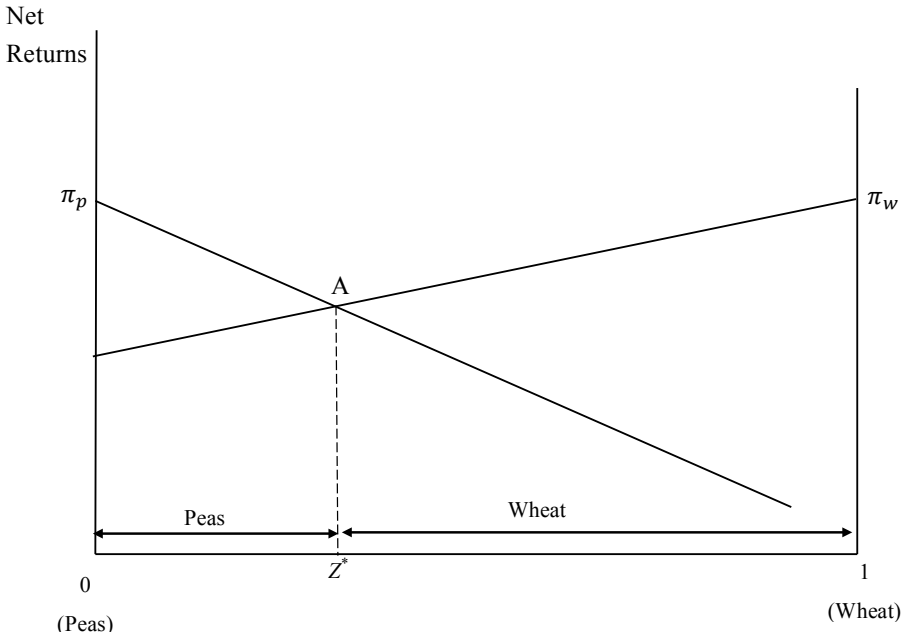

Figure 1: Farmers' Determination of Production: Before Rotation

profit function for wheat producers. The yield of wheat y_w is a function of y_p because higher pea production on a unit of land can increase wheat yield. Furthermore, the yield of peas y_p is determined by land quality z – the higher is land quality, the higher is pea yield – thus y_w is a function of z. A similar interpretation holds for f_{wt}, the per acre fertilizer cost (especially nitrogen cost) for wheat production, i.e., f_{wt} is a function of y_p because higher yield of peas on a unit of land can decrease the cost of fertilizer for wheat and because y_p is a function of z, consequently, f_w is a function of z as well. Parameters γ_p and γ_w are non-negative unit cost enhancement factors that are constant across all producers. It is assumed that $\gamma_p < \gamma_w$, which indicates pea crop is more cost effective than wheat because it uses less fertilizer such as nitrogen than wheat. The interpretation of $\gamma_p z$ is the additional cost incurred to individual farmer z, and the same interpretation holds for $\gamma_w z$.

The per acre industry knowledge stock of peas K_{pt} is determined by the historical R&D investment in pea industry, i.e., .

$$K_{pt} = \sum_{s=1}^{L_R} \omega_s E_{t-s} \qquad \forall\, t \in [1, L_R] \tag{2}$$

The industry knowledge stock K_{pt} is a public good for farmers within the pulse producer group at time period t.

For simplicity, assume the yield of wheat and peas, and the fertilizer are linear functions of land quality z. One step further, assume $y_p(z) = z$, $y_w(z) = az$, and $f_{wt}(z) = bz$ ($a \neq 0, b \neq 0$). Thus, equation (1) can be rewritten as

$$\pi_{pct} = p_{pt}(1 - l_p)z - \gamma_{pt}z + K_{pt} \qquad \text{per acre profit function for pea production} \quad (3a)$$

$$\pi_{wct} = (p_{wt} - l_w)az - bz - \gamma_{wt}z \qquad \text{per acre profit function for wheat production} \quad (3b)$$

When determining which crop to plant, a farmer with a differentiating land quality compares the profit of growing peas with the profit of growing wheat. As Figure 1 shows, the marginal farmer who is indifferent of growing peas and wheat is determined by the intersection of the profit functions at Z^*, i.e.,

$$Z^* = Q^s_{pct} = \frac{K_{pt}}{[(p_{wt} - l_w)a - b - \gamma_w] - [p_{pt}(1 - l_p) - \gamma_p]} \tag{4}$$

The equation shows the number of farmers who will be willing to plant peas. Under the assumption of fixed proportion and farmers are uniformly distributed in their land quality, the above equation is also the output supply function of peas.

Therefore, the supply of wheat Q^s_{wct} is $(1 - Q^s_{pct})$, i.e.,

$$Q^s_{wct} = \frac{[(p_{wt} - l_w)a - b - \gamma_w] - [p_{pt}(1 - l_p) - \gamma_p] - K_{pt}}{[(p_{wt} - l_w)a - b - \gamma_w] - [p_{pt}(1 - l_p) - \gamma_p]} \tag{5}$$

The aggregate benefit occurring to pea producers is given by the area below the per acre profit function for pea producers, i.e.,

$$W_{pct} = \int_0^{Z^*} \pi_{pt} dz = \int_0^{Z^*} (p_{pt}(1 - l_p)z - \gamma_p z + K_{pt})dz \tag{6}$$

The aggregate benefit occurring to wheat producers is given by the area below the per acre profit function for wheat producers, i.e.,

$$W_{wct} = \int_{Z^*}^{1} \pi_{wt} dz = \int_{Z^*}^{1} ((p_{wt} - l_w)az - bz - \gamma_w z)dz \tag{7}$$

Period 2: After Rotation (t=2)

It is assumed that farmers will rotate crops in period two, i.e., farmers who were growing peas in period one will grow wheat in period two, and wheat farmers in period one will grow peas in period two.

$$\pi_{pc(t+1)} = p_{p(t+1)}(1-l_p)z - \gamma_{p(t+1)}z + K_{p(t+1)} \qquad \text{per acre profit function for pea production} \tag{8a}$$

$$\pi_{wc(t+1)} = (p_{w(t+1)} - l_w)az - bz - \gamma_{w(t+1)}z \qquad \text{per acre profit function for wheat production} \tag{8b}$$

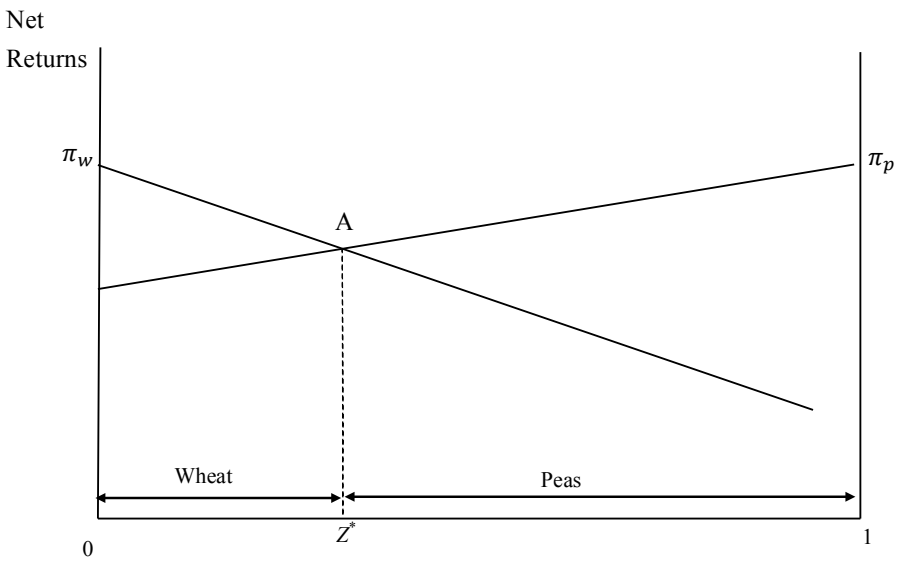

Figure 2: Farmers' Determination of Production: After Rotation

Stage 1: Determination of the Optimal Levy

The objective of the pulse producer group is to maximize net present value of the aggregate producer surplus, i.e., the marginal benefits of R&D investment, via determine the check-off ratio l_p (or R&D investment), i.e.,

$$\max_{l_p} \text{NPV (PS)} = \max_{l_p} \sum_{t=1}^{50} W_{pct}/(1+r)^t \tag{9}$$

Postinnovation: After R&D in Pea Industry

As Figure 3 shows, the model assumes that the MB_t are created by a change in the check-off ratio from l_p to l'_p at period $t = 0$; the check-off ratio then returns to the original level l_p in period $t = 1$ and all remaining periods.

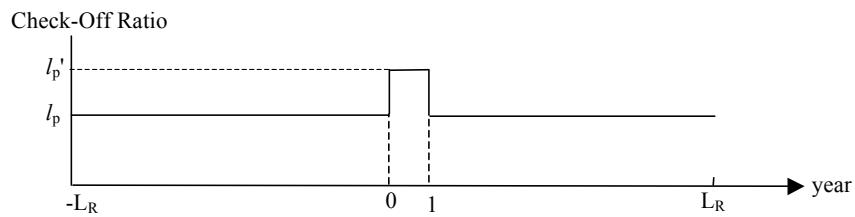

Figure 3: The Pattern of The Change in Check-Off Ratio

After the increase of R&D investment, i.e., the check-off ratio l_p, in pea industry in Canada, the knowledge stock increases from K_{pt} to K'_{pt} because of the increase in pea R&D investment E according to equation (2). The yield of wheat increases and fertilizer costs decrease due to the spillovers, i.e., $y_w(z) = a'z$, and $f_{wt}(z) = b'z$ ($a' > a$, $b' < b$). The per acre profit function for pea production increases from π_p to π'_p, and the per acre profit for wheat production increases from π_w to π'_w. Thus, equation (3) can be rewritten as

$$\pi'_{pct} = p_{pt}(1-l_p)z-\gamma_p z+K'_{pt} \quad \text{per acre profit function for pea production after R\&D} \quad (10a)$$

$$\pi'_{wct} = (p_{wt} - l_w)a'z - b'z - \gamma_w z \quad \text{per acre profit function for wheat production after R\&D} \quad (10b)$$

The marginal farmer after the increase in R&D investment in pea industry is located at Z_1 in Figure 4. Thus, the supply of peas after R&D is as follows:

$$Z_1 = Q^{s\prime}_{pct} = \frac{K'_{pt}}{[(p_{wt} - l_w)a' - b' - \gamma_w] - [p_{pt}(1 - l_p) - \gamma_p]} \quad (11)$$

The supply of wheat after R&D is

$$Q^{s\prime}_{wct} = \frac{[(p_{wt} - l_w)a' - b' - \gamma_w] - [p_{pt}(1 - l_p) - \gamma_p] - K'_{pt}}{[(p_{wt} - l_w)a' - b' - \gamma_w] - [p_{pt}(1 - l_p) - \gamma_p]} \quad (12)$$

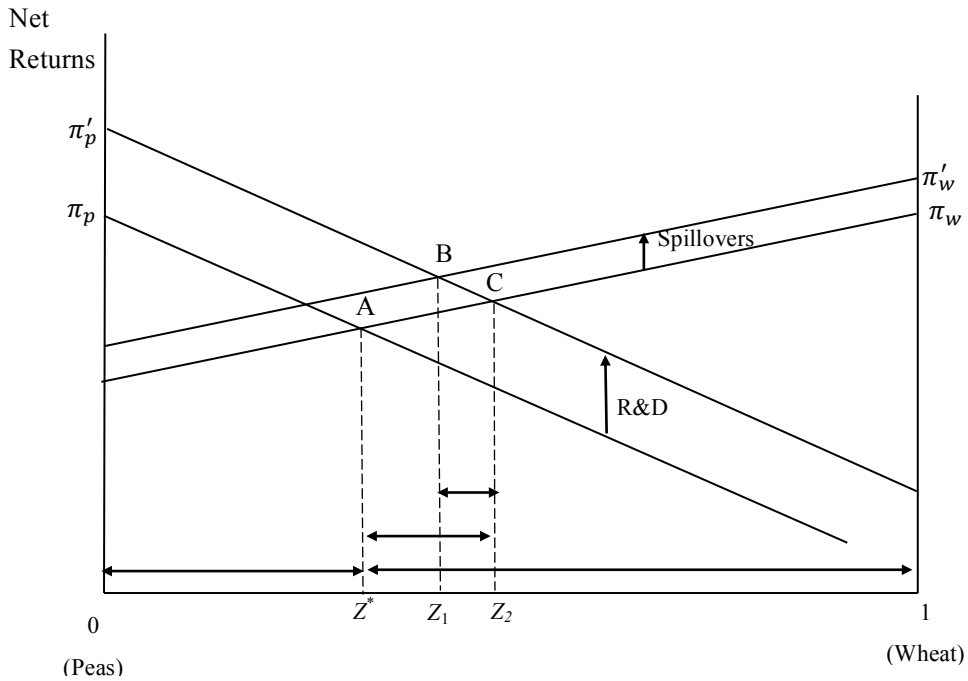

Figure 4: Farmers' Determination of Production: After Rotation

The aggregate benefit occurring to pea producers after R&D is

$$W'_{pct} = \int_0^{Z_1} \pi'_{pt} dz = \int_0^{Z_1} (p_{pt}(1 - l_p)z - \gamma_p z + K'_{pt}) dz \tag{13}$$

The aggregate benefit occurring to wheat producers after pea R&D is

$$W'_{wct} = \int_{Z_1}^{1} \pi'_{wt} dz = \int_{Z_1}^{1} ((p_{wt} - l_w)a'z - b'z - \gamma_w z) dz \tag{14}$$

Spillovers from Peas to Wheat

Spillovers from pea industry to wheat industry is defined as the increase of producer surplus of wheat before and after pea R&D investment, i.e.,

$$\begin{aligned} O &= W'_{wct} - W_{wct} \\ &= \textstyle\int_{Z_1}^{1} \pi'_{wct} dz - \int_{Z^*}^{1} \pi_{wct} dz \\ &= \textstyle\int_{Z_1}^{1} [(p_{wt} - l_w)a'z - b'z - \gamma_w z] dz - \int_{Z^*}^{1} [(p_{wt} - l_w)az - bz - \gamma_w z] dz \end{aligned} \tag{15}$$

Supply in Importing Countries

For simplicity, assume farmers in importing countries are homogeneous. The supply functions for peas and wheat in country i at period t are as follows:

$$Q^s_{pit} = \alpha_{pi} + \beta_{pi} p_{pt} \tag{16a}$$

$$Q^s_{wit} = \alpha_{wi} + \beta_{wi} p_{wt} \tag{16b}$$

Demand

On the demand side, a vertical product differentiation model will be used under the assumption that pulses are potentially superior to wheat products because it provides a wide variety of health benefits. They are high in fiber, protein, and iron, are low in fat and sodium, are free of cholesterol [SPG, 2009].

The consumers in each country are differentiated with respect to a characteristic A ($A \in [0, 1]$). Consumers with characteristic A has a utility function:

$$U_{pt} = U - p_{pt} - \theta_p A \qquad \text{per unit utility function for pea consumption} \tag{17a}$$

$$U_{wt} = U - p_{wt} - \theta_w A \qquad \text{per unit utility function for wheat consumption} \tag{17b}$$

where U_{pt} and U_{wt} are the per unit utilities for pea consumption and wheat consumption respectively. The corresponding prices are p_{pt} and p_{wt}. The parameter U is a per unit base level of utility, and the parameters θ_p and θ_w are nonnegative utility discount factors that are constant across all consumers. It is assumed that $\theta_p < \theta_w$ denoting higher health benefits of peas relative to wheat.

When determining which product to consume, a consumer with a differentiating characteristic compares the utility of consuming peas with the utility of consuming wheat. As Figure 5 shows, the marginal farmer who is indifferent of consuming peas and wheat is determined by the intersection of the utility functions at A^*, i.e.,

$$A^* = Q^d_{pt} = \frac{p_{wt} - p_{pt}}{\theta_p - \theta_w} \tag{18}$$

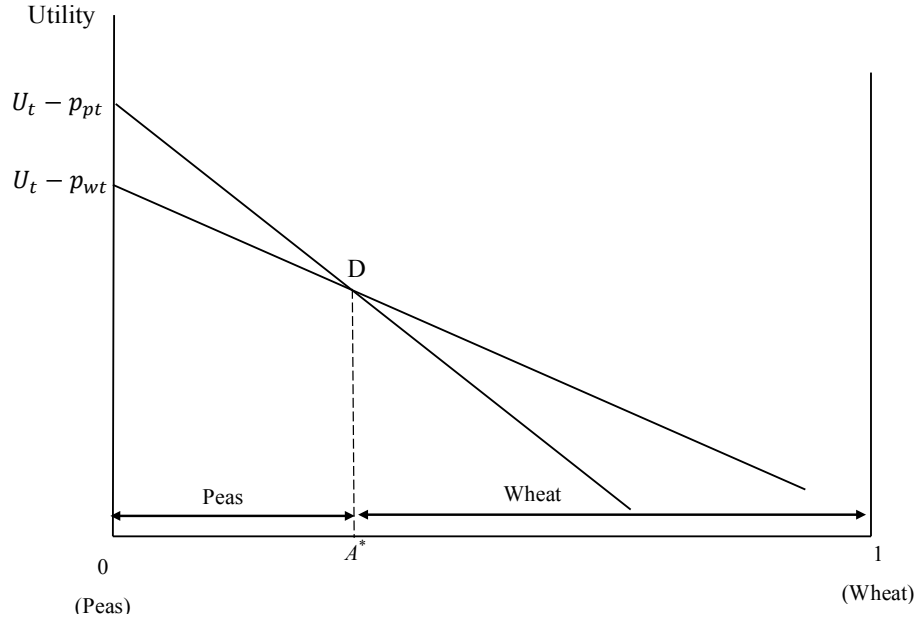

Figure 5: Vertical Product Differentiation Model for Wheat and Pea Consumption

The equation shows the number of consumers who will be willing to consume peas. Under the assumption that consumers are uniformly distributed in their characteristic, the above equation is also the demand function of peas.

Therefore, the demand of wheat Q^d_{wt} is $(1 - Q^d_{pt})$, i.e.,

$$Q^d_{wt} = 1 - A^* = \frac{\theta_p - \theta_w + p_{pt} - p_{wt}}{\theta_p - \theta_w} \tag{19}$$

The aggregate consumer surplus is given by the area below the utility curves. The consumer surplus for pea consumers is

$$S_{pt} = \int_0^{A^*} U_{pt} dA = \int_0^{A^*} (U - p_{pt} - \theta_p A) dA \tag{20}$$

The aggregate consumer surplus occurring to wheat consumers is

$$S_{wt} = \int_{A^*}^1 U_{wt} dA = \int_{A^*}^1 (U - p_{wt} - \theta_w A) dA \tag{21}$$

World Market Outcomes

The market outcomes for peas and wheat are determined by simultaneously solve the supply and demand equations.

$$Q^s_{ptc} + Q^s_{pti} = Q^d_{ptc} + Q^d_{pti} \tag{22a}$$

$$Q^s_{wtc} + Q^s_{wti} = Q^d_{wtc} + Q^d_{wti} \tag{22b}$$

Conclusions

The academic contribution of this research involves filling a gap in quantifying the spillovers across levy programs for R&D investment. To the best of the author's knowledge, no study has looked at the spillovers across levy programs and its impact on producer-funded R&D investment decisions.

Another contribution of this study is to provide policy implications for both governments and producer associations to support decision-making about the underinvestment issue of producer-funded R&D. In fact, there may be scope for government intervention that can be welfare enhancing. For instance, if it is found that spillovers across levy programs generate large impact on research returns to pulse producers, then a new mechanism to collect levies are in consideration.

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