R&D, Market Power, and Trade —The Case of Soybeans

Shu-Yi Liao*, Sheng-Tung Chen** and Chi-Chung Chen***

Abstract

The relationship between R&D and market power is a two-way one. In this study, a two-stage decision process is developed involving R&D, trade, and market power both in theory and by using an empirical model that is applied to soybeans. The impact of an increase in R&D on the soybean yield is incorporated into the international soybean market using an imperfect spatial equilibrium model together with the conjectural variation approach. The empirical results show that the major soybean exporters are price-takers while some of the import markets are characterized by imperfect competition. As the R&D-induced technical change in regard to soybean yields is incorporated into this empirical model, the empirical results show that both importers and exporters benefit from this improvement in yields. However, the way in which the welfare of trading countries is distributed may depend on both the improvement in yields and their market power.

Keywords: R&D, Market Power, Trade, Imperfect Spatial Equilibrium Model

JEL Classification: Q13, Q16, Q17

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I. Introduction

Traditional research on the benefits of R&D in agricultural commodities commonly assumes that the market structure is perfectly competitive (Edwards and Freebairn, 1984; Brennan and Bantilan, 2003; Brennan, et al., 2003). However, recent studies on international agricultural markets using the industrial organization approach indicate that many of the international agricultural commodity markets are characterized by imperfect competition (Rogers and Sexton, 1994; Alston, et al., 1997; Huang and Sexton, 1996). Besides, Raper and Noelke (2004) indicate that estimates of the degree of market power exertion have and continue to guide decisions regarding merger policy or antitrust enforcement in concentrated markets. Such policy decisions impact many market participants and necessitate that measures of firm and industry behavior be as accurate as possible. Thus, this section of the literature implies that market power has to be considered when analyzing the economic impact of R&D on the market.

In recent years, biotech development that has formed a part of R&D has played an important role in soybean variety and crop yield improvement. For instance, the ratio of biotech soybean to traditional soybean products in the United States in terms of acreage planted increased from 12.7% in 1997 to 81.0% in 2003, while 99.1% of soybean products in the year 2003 in Argentina came from biotech soybeans. Such new technological improvements resulting from R&D have had a significant impact on both the international and domestic soybean markets. This phenomenon had also happened to other agricultural commodity but not as significant as soybean had. Besides, the soybeans market had the characteristics that three exporters (Argentina, Brazil and U.S.) share 93% the world soybeans exports and Europe, China, Japan and Mexico account for about 80% soybeans imports. Therefore, the market power will play an important role in world soybeans market. And that is why we choose soybeans market as the target that we want to get the connection between the R&D, market power and trade. However, other biotech products including cotton, corn, and rice are also important research targets. The theoretical and empirical models of our manuscript could also apply for such commodities. In other words, the basic idea of the theoretical and empirical models and finding from this study could be generally applied to biotech and traditional agricultural commodities.

While the international soybean markets have received much attention in the literature (Uri et al., 1993; Goodwin et al., 2005), only a few papers have discussed the market power. Most studies have argued that the international soybean markets are close to being perfectly competitive markets and that the degree of government intervention in such markets is less than for other agricultural commodities (Liu and Wainio, 1989). However, national and international interests are not always in harmony over trade policy. A trading country has an incentive to set up either a tariff protection or an export subsidy/promotion program to maximize its own national interests at the expense of the international interests. For instance, Enke (1944) showed that an economy would benefit more from imports if the importing country were to act as a monopsonist by adopting a tariff duty. Larson and Rask (1992) and Uri et al. (1994) indicated that trading policies, such as tax and subsidy policies, export and import controls, and agricultural policies, have affected soybean production and market shares in a major way. Such studies have implied that government actions affect the soybean markets and result in price gaps.

On the other hand, the topic of estimating the effects of R&D on the world agricultural markets has recently been studied by Edwards and Freebairn (1984), Rogers and Sexton (1994), Huang and Sexton (1996), Falck-Zepeda et al. (2000), Anderson and Jackson (2003), Brennan and Bantilan (2003), Brennan et al. (2003), and many others. The major focus of these studies has been on the welfare impacts of innovations in biotechnology either on an individual country or on world markets. However, the market power has been ignored when evaluating the welfare impacts of a technological improvement. Huang and Sexton (1996) and Alston et al. (1997) have evaluated the effects of imperfect competition on the size and distribution of the benefits from the research. However, their study has only focused on the domestic market.

The main purpose of this study is to develop a framework to evaluate the economic impacts of soybean yield improvements due to increased R&D on international soybean markets while also giving consideration to market power. The impacts of increased R&D on soybean yields is observed from the study by Soper et al. (2003), while the second step is to incorporate the conjectural variation approach into an imperfect spatial equilibrium model to determine the market power of international soybean markets. Finally, the impacts of increasing R&D on soybean yields are incorporated into this empirical model to estimate the economic impacts of prices, trade, and welfare on world soybean markets. The R&D that has taken place in the U.S. agricultural sector will serve as an example to show the relationship between improvements in soybean yields and the R&D level. The second section of this paper introduces the international soybean markets while the theoretical model is illustrated in the third section. The empirical model is developed and tested in the fourth section and the simulation results are illustrated in the fifth section. Final section is conclusion.

II. International Soybean Markets

In the international soybean markets, the United States is currently the most important producing country with 85,741 thousand metric tons of soybeans accounting for 41.54% of world production in 2004. The second largest producing country is Brazil (23.84%), followed by Argentina (15.50%) as shown in Table 1. These three countries together produced almost 80% of the soybeans in the world in 2004. According to the statistical databases of the Food and Agriculture Organization of the United Nations (FAO), the United States is the largest exporting country and exported 900 million bushels of soybeans in 2003 or 40% of soybeans exported, followed by Brazil which contributed 37% of the world's exports of soybeans. The third largest exporting country was Argentina with a 16% share of the world's soybean exports.

Therefore, these three countries together accounted for 93% of soybean exports in 2003. And the percentage shares of world soybean market by major exporters from 1991 to 2001 are shown in Figure 1.

A similar situation is seen to occur in the market for soybean imports. Europe, China, Japan and Mexico together account for about 80% of soybean imports in world markets as shown in Figure 2. The statistics in Figure 2 also show that the market shares of both Europe and Japan in world soybean markets decreased in the last decade while that of China increased over the same period. The statistics in Figures 1 and 2 imply that the major countries control the export and import shares of soybean markets and there might have imperfect competition in the world soybean markets.

The soybean yields in metric tons per hectare for major exporting countries are displayed in Figure 3. The soybean yield in Brazil has steadily increased over the last 15 years. For example, the soybean yield in Brazil in 1991 was about 1.6 metric tons per hectare but increased to 2.8 metric tons per hectare around the year 2000. Such an improvement in yields in Brazil may have caused her share of the world market to increase as shown in Figure 1. The U.S. may have experienced a similar improvement in soybean yields as Brazil, but on a smaller scale, while Argentina exhibited larger yield variations as shown in Figure 3.

Table 1 Soybean production and market shares of the main countries

(1,000 metric tons, %)

Year	World	Argentina	Brazil	China	U.S.	Others
1990	108,453	10,700	19,898	11,008	52,416	14,431
	(100.00%)	(9.87%)	(18.35%)	(10.15%)	(48.33%)	(13.31%)
1991	103,310	10,862	14,938	9,721	54,065	13,724
	(100.00%)	(10.51%)	(14.46%)	(9.41%)	(52.33%)	(13.28%)
1992	114,450	11,310	19,215	10,312	59,612	14,001
	(100.00%)	(9.88%)	(16.79%)	(9.01%)	(52.09%)	(12.23%)
1993	115,153	11,045	22,591	15,323	50,886	15,309
	(100.00%)	(9.59%)	(19.62%)	(13.31%)	(44.19%)	(13.29%)
1994	136,463	11,720	24,932	16,011	68,445	15,355
	(100.00%)	(8.59%)	(18.27%)	(11.73%)	(50.16%)	(11.25%)
1995	126,981	12,133	25,683	13,511	59,174	16,480
	(100.00%)	(9.55%)	(20.23%)	(10.64%)	(46.60%)	(12.98%)
1996	130,213	12,448	23,155	13,234	64,782	16,594
	(100.00%)	(9.56%)	(17.78%)	(10.16%)	(49.75%)	(12.74%)
1997	144,416	11,005	26,391	14,737	73,177	19,106
	(100.00%)	(7.62%)	(18.27%)	(10.20%)	(50.67%)	(13.23%)
1998	160,101	18,732	31,307	15,153	74,599	20,310
	(100.00%)	(11.70%)	(19.55%)	(9.46%)	(46.59%)	(12.69%)
1999	157,802	20,000	30,987	14,245	72,223	20,347
	(100.00%)	(12.67%)	(19.64%)	(9.03%)	(45.77%)	(12.89%)
2000	161,405	20,200	32,735	15,411	75,055	18,004
	(100.00%)	(12.52%)	(20.28%)	(9.55%)	(46.50%)	(11.15%)
2001	176,761	26,864	37,881	15,407	78,671	17,937
	(100.00%)	(15.20%)	(21.43%)	(8.72%)	(44.51%)	(10.15%)
2002	180,910	30,180	42,125	16,507	74,825	17,272
	(100.00%)	(16.68%)	(23.29%)	(9.12%)	(41.36%)	(9.55%)
2003	189,213	34,800	51,482	15,658	66,778	20,495
	(100.00%)	(18.39%)	(27.21%)	(8.28%)	(35.29%)	(10.83%)
2004	206,410	32,000	49,205	17,750	85,741	21,713
	(100.00%)	(15.50%)	(23.84%)	(8.60%)	(41.54%)	(10.52%)

Data source: Statistical databases from the Food and Agriculture Organization of the United Nations.

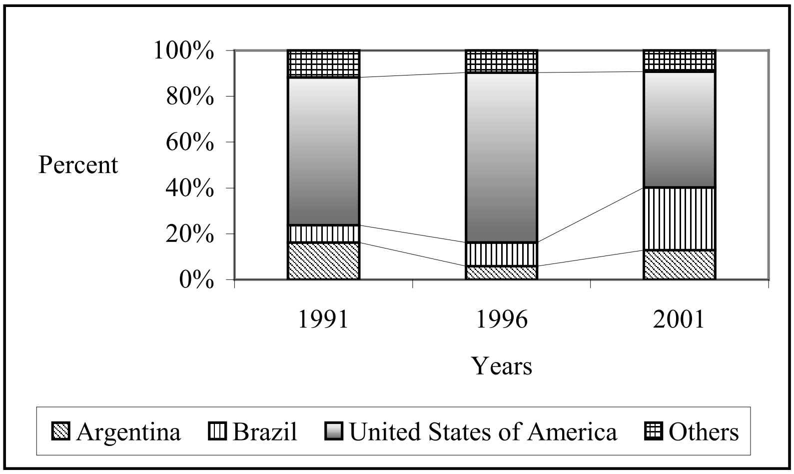

Figure 1　Percentage shares of world soybean market by major exporters

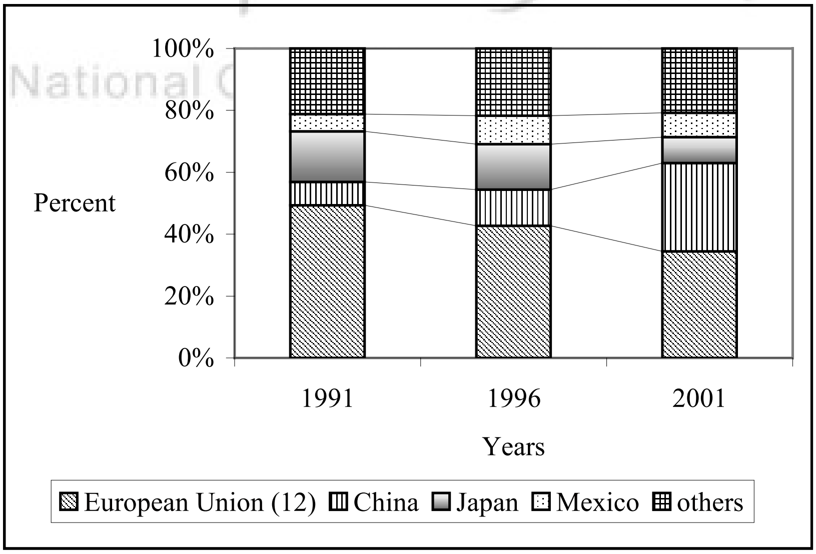

Figure 2　Percentage shares of world soybean market by major importers

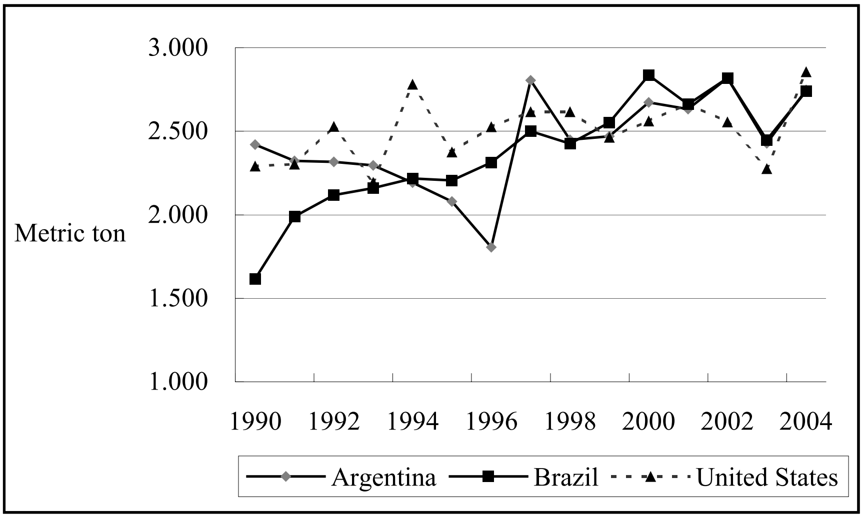

Figure 3 Comparative yields of major soybean producing countries

III. Theoretical Model

Therefore, the relationship between R&D and market power in a trade model will be developed in this theoretical model. Suppose there are *m* importing countries and *n* exporting countries in the world soybean market. The inverse excess supply function of exporting country *i*, $i = 1,\cdots, n,$ is assumed to be of a constant elasticity type as follows:

$$P_i = g(E_i) = c_i E_i^{\frac{1}{\varepsilon_i}} \tag{1}$$

where P_i and E_i denote the export price and volume, and c_i and are the constant parameter and the elasticity of the excess supply curve for the i^{th} exporting country, respectively. Furthermore, the inverse demand function of exporting country j, $j = 1, \cdots, n$ is also assumed to be of a constant elasticity type as follows:

$$P_j = f(M_j) = a_j M_j^{\frac{1}{\eta_j}} \tag{2}$$

where P_j and M_j denote the import price and volume, respectively, and a_j and η_j are the j^{th} importing country, respectively.

The theoretical model is developed by means of a two-stage decision process following the idea of strategic trade policy by Brander (1995). In the first stage, the government of the exporting country has to decide the optimal R&D level. In the second stage, firms decide the trading volume under the possible trading policy with a given R&D level. This two-stage decision process implies that the optimal R&D and trade volume relationship is a two-way one. The reason why we assume the R&D level is decided by the government is because the benefits from R&D in many agricultural commodities give rise to spillover effects (Alston and Pardey, 2001; Brennan and Bantilan, 2003; Brennan et al., 2003).

Suppose there is a state trading enterprise (STE) in an exporting country exports a homogenous product and competes in quantity with the foreign market agents in an international market in the second stage. This exporting STE maximizes its profit given a R&D volume R_i with the subsidy policy s_i. The objective function and equilibrium conditions are as follows:

$$\underset{X_{ij}}{Max}: \pi_i = \sum_j P_j X_{ij} - \int P_i(E_i; R_i) dE_i - \sum_j TC_{ij} * X_{ij} - (v_i - s_i) * R_i \tag{3}$$

$$\frac{\partial \pi_i}{\partial X_{ij}} = P_j + X_{ij}\Big(1 + \sum_{i' \neq i} \frac{\partial X_{i'j}}{\partial X_{ij}}\Big) f' - P_i(E_i, R_i) - TC_{ij} = 0 \tag{4}$$

where TC_{ij} is the transportation cost from exporting country i to importing country j and f' is the slope of the inverse demand function in importing country j, s_i and v_i are the unit subsidy and unit cost on R&D.

Equation (4) indicates that the trade volume of this exporting country depends on its R&D level as well as trade volume from foreign firms. The term $\frac{\partial X_{i'j}}{\partial X_{ij}}$ in equation (4) following Varian (1992) is the conjectural variation for the STE in exporting country i, and indicates the expected change in the i'^{th} country's exports to country j due to changes in the volume exported by country i to importing country j. The conjectural variation in equation (4) reflects the trading country's strategic behavior toward trade. For example, if the term $\frac{\partial X_{i'j}}{\partial X_{ij}}$ in equation (4) is -1, then the price difference will be equal to the transportation cost, which implies that exporting country i is a price-taker. Otherwise, the price difference will be the transportation cost plus a positive term $-X_{ij}(1+\sum_{i'\neq i}\frac{\partial X_{i'j}}{\partial X_{ij}})f'$, which could be defined as the price mark-up (or market rent).

Spencer and Brander (1983) have pointed out that government can be introduced as an agent to setup a subsidy rate on R&D expenditure in a period before firms spend on R&D. Suppose that the government of exporting country i maximizes its domestic welfare by setting an optimal subsidy on R&D in the preceding stage. So, the objective function of exporting country i is as follows:

$$\underset{s_i}{Max}: G_i(s_i) = \sum_j P_j X_{ij} - \int P(E_i; R_i)dE_i - s_i * R_i \tag{5}$$

The first term of equation (5) is the trade revenue, while the second term represents the area under the excess supply curve and the third term (R_i) is the total expenditure on R&D that the government subsidizes. The first-order condition of the maximization can be written as:

$$\frac{\partial G_i(s_i)}{\partial s_i} = \left\{ \sum_j (X_{ij}\frac{\partial P_j}{\partial R_i} + P_j\frac{\partial X_{ij}}{\partial R_i}) - P_i\frac{\partial E_i}{\partial R_i} \right\} * \frac{\partial R_i}{\partial s_i} - s_i = 0 \tag{6}$$

Therefore, the function of optimal R&D subsidy can be displayed as the function of trade volume.

Finally, the optimal R&D level for a firm could be decided from its profit function as shown in equation (3) when the optimal subsidy on R&D is made by government. The demand for optimal R&D function will be shown in equation (7).

$$R_i^* = f_i(E_i, s_i) \tag{7}$$

Equations (4) and (7) show the relationship between the optimal R&D level and the trade volume. As R&D increases after government subsidizes, the total export volume increases due to the shift in the domestic supply curve. However, the changes in the magnitude of the trade volume depend on the level of marketing power (or conjectural variations terms, CV terms hereafter). The alternative CV terms with changes in R&D subsidy may be illustrated as explained below.

A similar decision process can be applied for an importing country. However, the governments in most importing countries may not engage in R&D in the agricultural sector due to the disadvantageous production conditions. Therefore, the decision process for an importing country is modified to become one stage. If we suppose that the importing state trading enterprise (ISTE) in importing country *j* maximizes the consumer's surplus (or net trade surplus) while exercising her market power, the objective function will be as follows:

$$\underset{X_{ij}}{Max}: \phi_j = \int P(M_j)dM_j - \sum_i P_i X_{ij} - \sum_i TC_{ij} * X_{ij} \tag{8}$$

where the first term of the ϕ_j function indicates the area under the excess demand curve of importing country j, and the second and third terms refer to the cost of acquiring imports and the transportation cost. The first-order condition is expressed as follows:

$$\frac{\partial \phi_j}{\partial X_{ij}} = P_j - P_i - TC_{ij} - X_{ij}(1 + \sum_{j'} \frac{\partial X_{ij'}}{\partial X_{ij}})g' = 0, \ \forall i, j. \tag{9}$$

where $\frac{\partial X_{ij'}}{\partial X_{ij}}$ is the conjectural variation for importing country j and g' is the slope of the inverse demand function in importing country i. The term $\frac{\partial X_{ij'}}{\partial X_{ij}}$ in equation (9) refers to the change in the trade with country j' of exporting country i caused by a change in the amount imported by importing country j from exporting country i. Similarly, this CV term represents the degree of imperfect competition in the market.

IV. Empirical Model

The conjectural variations in equations (4) and (9) reflect the trading country's strategic behavior toward trade. For example, if the term $\frac{\partial X_{i'j}}{\partial X_{ij}}$ in equation (4) is negative, then the price difference will be equal to the transportation cost, which implies that exporting country i is a price-taker. Otherwise, the price difference will be the transportation cost plus a positive term $X_{ij}(1+\sum_{i'\neq i}\frac{\partial X_{i'j}}{\partial X_{ij}})f'$, which could be defined as the price mark-up (or market rent).

The conjectural variations in Nelson and McCarl (1984) and the models of Kawaguchi et al. (1997) are each assumed to be constant. This assumption implies a specific type of marketing power or a specific trading behavior. We follow the same assumption with regard to this parameter. By combining the two first-order conditions [i.e. (4) and (9)], the profit and net surplus maximization problem for all importers and exporters can be re-specified as a net social payoff maximization problem adjusted for imperfectly competitive markets. The model can be specified as follows:

$$\begin{aligned} \underset{X_{ij}}{Max}\ \omega = & \sum_j \int P(M_j)dM_j - \sum_i \int P(E_i)dE_i - \sum_i \sum_j TC_{ij}X_{ij} \\ & + \sum_i \sum_j a_j \eta_j \frac{X_{ij}^2}{2}(1+A_{ij}) - \sum_i \sum_j c_i \varepsilon_i \frac{X_{ij}^2}{2}(1+B_{ij}) \\ s.t. \quad & M_j - \sum_i X_{ij} \le 0, \qquad \forall j, \\ & -E_i + \sum_j X_{ij} \le 0, \qquad \forall i, \end{aligned} \tag{10}$$

where A_{ij} is the conjectural variation for exporting country i when selling to country j that shows how other exporters selling to country j react to changes in country $i's$ export sales. The term B_{ij} is the conjectural variation for importing country j when buying from country i which explains how other importers buying from country i react to changes in country $j's$ import purchases. Mathematically, $A_{ij} = \frac{\sum_{i',i'\neq i}^{n} X_{i'j}}{\partial X_{ij}}$, and $B_{ij} = \frac{\sum_{j',j'\neq j}^{n} X_{ij'}}{\partial X_{ij}}$.

In this objective function, the first and second terms determine the areas under the excess demand curves minus the areas under the excess supply curves while the third term subtracts the transport costs. Collectively, these three terms follow those from the classical spatial equilibrium model (Takayama and Judge, 1971) and represent trade under perfect competition (or free trade). The fourth and fifth terms incorporate the conjectural variations and represent, respectively, the export and import market rents due to imperfect competition.

Optimizing yields the following Kuhn-Tucker conditions when trading activity exists

$$\frac{\partial \omega}{\partial X_{ij}} = P_j - P_i - t_{ij} + a_j \eta_j (1+A_{ij})X_{ij} - c_i \varepsilon_i (1+B_{ij})X_{ij} = 0 \tag{11}$$

where P_j is the import price for importing country j and P_i is the export price for exporting country i.

A wide variety of market behavior can be reflected by the *CV* terms: A_{ij} and B_{ij}. If both equal -1, then exporter i and importer j will be acting as perfect competitors as in the Takayama and Judge model. If A_{ij} equals zero while B_{ij} equals -1, then exporting country i will act as an imperfect competitor who will not change her exports in response to i's action in a Cournot-Nash context, while importer j will behave as a price-taker.

If the exporter's conjectural variation is positive and the importer's conjectural variation is -1, this will imply that collusion or cooperation exists among exporting countries. For instance, if each derivative term in the conjectural variation A_{ij} equals the ratio of the traded quantities, i.e.,

$$\frac{\partial X_{i'j}}{\partial X_{ij}} = \frac{X_{i'j}}{X_{ij}}, \forall i' \neq i,$$

then the whole world will act as a perfectly discriminating monopolist against importer j. On the other hand, if the exporter's conjectural variation is smaller than -1, this implies that a subsidy policy exists so that the export price is higher than the import price. Similar statements can be made on the import side.

Finally, if the exporter's and the importer's conjectural variations are not simultaneously equal to -1, then both markets will be imperfectly competitive. This indicates that exporting country i's market rent is $[a_j \eta_j (1 + A_{ij}) X_{ij}]$, while importing country j's market rent is $[c_i \varepsilon_i (1 + B_{ij}) X_{ij}]$.

This model will be applied to the world soybean market. The data on soybeans including their production, consumption, quantities traded and values in the year 2002 are obtained from the FAOSTAT database which is built by Food and Agriculture Organization of the United Nations. There are 19 major importing countries or regions and seven major exporting countries that are included in this empirical model. The country codes are listed in the Table 2. The model is calibrated and the percentage deviations between optimal production and consumption and the observed data for importers and exporters are shown in Tables 3 and 4. Both tables show that most of the deviations are within the acceptable tolerance level and, therefore, the model is validated.

The strategic behavior of a trading country can be examined by looking at the size of the estimated CV terms that are shown in Table 5. Generally speaking, we find that most soybean exporters behave as price-takers. For instance, the CV terms for the major exporters such as the U.S., Argentina, Brazil, INA and WSAF are –1, which means that they are all price-takers. These estimation results are similar to the findings in Liu and Wainio (1989). Meanwhile, the CV term in the LAM region is 3, which implies that there is some policy intervention in these countries or regions. This finding is consistent with the views of Larson and Rask (1992), who indicate that the changing competitiveness of world soybean markets may be evaluated relative to government policy and natural resources. Similarly, many import markets may be characterized by imperfect competition due to the implementation of policies. For example, the CV terms for Japan, Korea, and the Philippines are –0.6, –0.3, and 25, respectively, all of which deviate from –1, implying that imperfectly competitive markets exist in these countries. Such estimations are similar to those of Larson and Rask (1992) and Uri, et al. (1994).

Table 2 The trading country codes

Code	Importing Countries or Areas
AUS	Australia
JPN	Japan
KOR	Republic of Korea, Dem. People's Rep. of Korea
EU	Austria, Belgium, Denmark, Germany, Greece, Ireland, Italy, Netherlands, Portugal, Spain, United Kingdom
IND	Indonesia
MYS	Malaysia

Table 2 The trading country codes (continue)

Code	Importing Countries or Areas
PHL	Philippines
SGP	Singapore
THA	Thailand
TWN	Taiwan
MEX	Mexico
FRA	France
USSR	Armenia, Azerbaijan, Belarus, Estonia, Georgia, Kazakhstan, Kyrgyzstan, Latvia, Lithuania, Russian Federation, Tajikistan, Turkmenistan, Ukraine, Uzbekistan
ENOE	Albania, Bosnia, Bulgaria, Croatia, Czech, Czech Republic, Faeroe Islands, Finland, Hungary, Iceland, Liechtenstein, Malta, Norway, Poland, Romania, Slovenia, Sweden, Yugoslavia
SEA	Nepal, Cambodia, Burma, Bhutan, Laos, Mongolia, Vietnam, Brunei, Sri Lanka, Maldives, Bangladesh, Palau
NWMA	Pakistan, Afghanistan, Moldovia, Kyrgyz, Kuwait, Iran, Turkey, Israel, Syria, Iraq, Bahrain, Lebanon, Jordan, Yemen, Saudi Arabia, Qatar, United Arab Emirates, Oman, Cyprus
NEMAF	Eastern, Middle, Northern countries, Egypt
WSAF	Southern Africa, Western African countries
ROW	Rest of the World
Code	**Exporting Countries or Areas**
CAN	Canada
US	United States of America
CHN	People's Rep. of China, Hong Kong, Macao
ARG	Argentina
BRA	Brazil
INA	India
LAM	Antigua and Burbuda, Grenada, St. Lucia, St. Christopher, Commonwealth of Dominica, Jamaica, Haiti, Dominican Republic, Panama, Cuba, Bahamas, Costa Rica, Salvador, Nicaragua, Trinidad, Honduras, Belize, Barbados, Guatemala, Paraguay, Colombia, Guyana, Venezuela, Peru, Uruguay, Suriname, Chile, Bolivia, Ecuador

Table 3 Model validation for importers

Trading Code	Observed Data		Model Solution		Deviation	
	Production (metric tons)	Consumption (metric tons)	Production (metric tons)	Consumption (metric tons)	Demand (%)	Supply (%)
CAN	2495761	2553390	2569897	2569897	0.65	2.97
JPN	288716	5309037	280398	5376443	1.27	−2.88
KOR	507576	2038988	491347	1987024	−2.55	−3.20
EU	872353	18939293	873984	19179735	1.27	0.19
IND	719179	2038157	696489	2031836	−0.31	−3.15
MYS	NA	633920	NA	652941	3.00	NA
PHL	NA	265095	NA	256907	−3.09	NA
SGP	NA	19477	NA	19788	1.60	NA
THA	277817	1787722	276245	1768675	−1.07	−0.57
CHN	17638588	30079911	17498760	30979444	2.99	−0.79
TWN	393	2528618	385	2465265	−2.51	−1.97
MEX	92476	4468726	92583	4452547	−0.36	0.12
FRA	222823	1203892	228635	1243963	3.33	2.61
USSR	627765	812054	647898	755472	−6.97	3.21
ENOE	614757	919865	613033	950368	3.32	−0.28
SEA	285163	5641455	266651	5672653	0.55	−6.49
NWMA	253546	564759	243932	568130	0.60	−3.79
NEMAF	38873	366253	38219	369976	1.02	−1.68
ROW	NA	621624	NA	641890	3.26	NA
TOTAL	24935786	80792236	24818456	81942954	0.00	−0.01

Note: NA means data is not available.

Table 4 Model validation for exporters

Trading Code	Observed Data		Model Solution		Deviation	
	Production (metric tons)	Consumption (metric tons)	Production (metric tons)	Consumption (metric tons)	Demand (%)	Supply (%)
AUS	67317	60893	70560	70560	15.88	4.82
US	79952374	47501355	79871028	48775421	2.68	–0.10
ARG	32248180	29321911	32894164	28890820	–1.47	2.00
BRA	45011634	27200093	47046141	27414340	0.79	4.52
INA	4870458	4556385	4828804	4693886	3.02	–0.86
LAM	5199062	2887436	5273352	3014533	4.40	1.43
WSAF	483053	447566	471664	471554	5.38	–2.36
TOTAL	167832078	111975639	170455713	113331114	–0.02	–0.01

Table 5 Conjectural variations for soybean exporters and importers

Exporters	AUS	US	ARG	BRA	INA	LAM	WSAF
CVs	–1.00	–1.00	–1.00	–1.00	–1.00	3.00	–1.00
	CAN	JPN	KOR	EU-12	IND	MYS	PHL
	–0.80	–0.60	–0.30	–1.00	–1.00	–1.00	25
Importers	THA	CHN	TWN	MEX	FRA	USSR	ENOE
CVs	–1.00	–0.80	–0.40	–1.00	–1.00	–1.00	–1.00
	SEA	NWMA	NEMAF				
	–1.00	–1.00	–1.00				

V. Model Simulations

To estimate the impact of R&D on the international soybeans market, the effects of R&D on the soybean yield have to be evaluated first. To do so, the U.S. case will be applied here since the U.S. is the major soybean exporter and thus has a big incentive to invest in R&D in relation to soybean products in order to obtain more benefits from the international market. The parameter β in the following regression might possibly reflect the impact of R&D on the soybean yield:

$$Y = \alpha * RD + \beta * Trend + \varepsilon$$

where *Y* is the soybean yield per acre and *RD* is the U.S. Federal R&D budget in agriculture, while *Trena* is the time trend and ε is the error term.

The data set covers the period from 1986 to 2001 where the soybean yield per acre is obtained from USDA Agricultural Statistics while the source of the U.S. Federal R&D budget is the National Science Foundation, Division of Science Resources Studies (NSF/SRS). The U.S. soybean yield was 33.3 bushels per acre in 1986 and increased to 39.6 bushels per acre in 2001. At the same time, R&D expenditure amounted to US$1,083 million at 1996 constant dollar prices in 1986 and increased to US$1,329 million in 2001, reflecting an annual R&D rate of increase of about 3.98%. In order to escape the effect of the time trend, we set the trend as an explanatory variable in our simple ordinary least squares model. The results were as follows:

$$\hat{Y} = \underset{(t\text{–}value=21.9)}{0.029 * RD} + \underset{(t\text{–}value=0.82)}{0.134 * trend}$$

The estimation of the parameter α was 0.029, which was significant and which indicates that the U.S. soybean yield will increase by 2.9% if the U.S. government increases the

Federal R&D budget by 1%. The share of the U.S. Federal budget devoted to agricultural R&D increased on average by 3.98% in each year between 1986 and 2001. Therefore, the soybean yield increased by 4.62% per year on average.

Soper et al. (2003) indicate that an indication of the impact of plant breeding and biotechnology investments on soybean yield. Soybean yield in 1973 was approximately 28 bushels per acre and was increased to 38 bushels per acre in 2001 which is about 4.62% increasing in soybean yield. Therefore, this number will be adopted here to represent the impacts of R&D on soybean yield.

To estimate the respective impacts of increased R&D expenditure and alternative marketing power on the international soybean markets, four scenarios were defined for our purposes. The first one assumed that there was no more investment in R&D given the 2002 international soybean marketing power. This was the Base scenario. The second scenario assumed that only the U.S. increased its R&D which resulted in a 4.62% increase in domestic soybean production. The third scenario assumed that, as the U.S. soybean yield increased, its export rival Brazil changed its behavior (i.e. the CV value changed) to against such technology improvement. The last scenario assumed that the U.S. also behaved as a Cournot player (i.e. the CV value was zero), with the same increase in soybean yield while observing the economic outcomes in the international soybean market. The meaning of last two scenarios is to observe the economic impacts of alternative players' behavior due to yield improvement by R&D. The definitions of each scenario are presented as follows:

Scenario 1. Base scenario.

Scenario 2. A 4.62% increase in the U.S. soybean yield.

Scenario 3. A 4.62% increase in the U.S. soybean yield while Brazil became a Cournot-Nash player.

Scenario 4. A 4.62% increase in the U.S. soybean yield while the U.S. behaved as a Cournot-Nash player.

The economic impacts of each scenario on the international soybean market are shown in Table 6. Current soybean production in the world is around 195 million metric tons where 57 million metric tons is the soybean trading volume as depicted by Scenario 1 in Table 6. The average export price is US$189 per metric ton while the average import price is US$225 per metric ton resulting in a US$240 billion trade surplus. As scenario 2 shows, while the soybean yield increased by 4.62% in the U.S. alone, the total world production and trading volume increased by 1.53% and 1.76%, respectively. Such increases in world production and trading volume resulted in a 3.63% decrease in the world price and a US$650 increase (0.27%) in the trade surplus. Scenario 3 displays that as the soybean yield increased by 4.62% in the U.S. and its export rival Brazil changed its behavior from being a price-taker to becoming a Cournot-Nash player (i.e. by allowing the CV for Brazil to be zero), total soybean trading volume resulted in a decrease in welfare as both the import and export prices rose and world production slightly increased. These estimates indicate that the market power may destroy the benefits of the international soybean market due to the higher yield from soybeans in the U.S. In other words, the market power and the improvement in yield (or R&D) simultaneously affect the economic outcome in the world soybean market.

A similar situation occurs in the case of Scenario 4. If the U.S. changes its behavior from being a price-taker to behaving as a Cournot-Nash player with the same soybean yield improvement (i.e. Scenario 4), then the world production will increase less than Scenario 2, but the trading volume will decrease by 11.75% with welfare declining by 1.18%. That means that if the U.S. does not adhere to the perfectly competitive market assumption by causing the market to become imperfect, the world soybean market will experience a sharp increase in its import price that will cause the overall welfare to decrease by 1.18%. The comparisons in terms of the economic outcomes in the world soybean market between Scenarios 3 and 4 indicate that the welfare distribution of the R&D benefit is significantly related to the market power.

Table 6 The economic impacts of R&D on the international soybean market

	World Production (metric tons)	Total Trade (metric tons)	Total Welfare ($US Million)	Import Price ($US/metric ton)	Export Price ($US/metric ton)
Scenario 1	195274200	57124598	240091	225	189
Scenario 2	198261900	58132476	240741	217	182
	(1.53%)	(1.76%)	(0.27%)	(–3.27%)	(–3.63%)
Scenario 3	197593200	55207477	239814	239	187
	(1.19%)	(–3.36%)	(–0.12%)	(6.59%)	(–1.11%)
Scenario 4	197723900	50413470	237267	316	190
	(1.25%)	(–11.75%)	(–1.18%)	(40.63%)	(0.79%)

The economic outcomes in relation to the major importers and exporters due to the increased R&D volume with alternative kinds of market behavior are shown in Tables 7 and 8. Table 7 shows that the consumption, trading volume, and welfare in all of the importing countries in Scenario 2 increase while production decreases as the U.S. soybean yield increases, leading to a reduction in the import prices. We also find that the most benefit goes to the country with the largest market share. The increase in welfare in Europe is the largest as compared with other importers, which indicates that the benefits enjoyed by the importers due to the improved yields of the exporters depend on the market share.

Besides, based on trade theory, the price mark-up will be increased when trade market is transferred from a perfect competitive market to an imperfect market. Scenario 4 simulated a Cournot-Nash behavior for U.S., therefore, the exporting price for U.S. will be decreased while the importing prices will be increased based on the equilibrium condition as shown in equation (11).

Table 7 Changes for importing countries

Country or Area	Scenario	Production (metric tons)	Consumption (metric tons)	Trade Volume (metric tons)	Welfare ($ million)	Price ($)
JPN	Scenario 1	280399	5376446	5096101	7434	236
	Scenario 2	–0.06%	1.39%	1.47%	0.21%	–2.99%
	Scenario 3	0.12%	–2.73%	–2.88%	–0.49%	6.29%
	Scenario 4	0.38%	–7.74%	–8.19%	–1.34%	19.43%
KOR	Scenario 1	491348	1987025	1495697	3203	231
	Scenario 2	–0.05%	1.14%	1.53%	0.15%	–3.03%
	Scenario 3	0.10%	–2.07%	–2.78%	–0.31%	5.86%
	Scenario 4	0.31%	–6.10%	–8.20%	–0.92%	18.68%
EU	Scenario 1	873984	19179742	18305758	20211	206
	Scenario 2	–0.37%	2.05%	2.16%	0.40%	–3.64%
	Scenario 3	0.63%	–3.38%	–3.57%	–0.69%	6.49%
	Scenario 4	1.83%	–9.42%	–9.96%	–2.03%	19.85%
IND	Scenario 1	696490	2031836	1335347	3249	222
	Scenario 2	–0.34%	0.81%	1.41%	0.13%	–3.37%
	Scenario 3	0.59%	–1.36%	–2.37%	–0.22%	6.01%
	Scenario 4	1.70%	–3.88%	–6.79%	–0.67%	18.39%
MYS	Scenario 1	NA	652941	652941	1172	222
	Scenario 2	NA	0.81%	0.81%	0.10%	–3.37%
	Scenario 3	NA	–1.36%	–1.36%	–0.17%	6.01%
	Scenario 4	NA	–25.28%	–25.28%	–6.03%	246.73%
PHL	Scenario 1	NA	256908	256908	624	382
	Scenario 2	NA	0.82%	0.82%	0.21%	–3.42%
	Scenario 3	NA	–0.35%	–0.35%	0.10%	1.53%
	Scenario 4	NA	–22.57%	–22.57%	–4.92%	198.02%
THA	Scenario 1	276246	1768676	1492430	2762	222
	Scenario 2	–0.34%	0.81%	1.02%	0.12%	–3.37%
	Scenario 3	0.59%	–1.36%	–1.72%	–0.21%	6.01%
	Scenario 4	10.57%	–20.98%	–26.82%	–5.45%	173.24%
CHN	Scenario 1	17498760	30979448	13480688	59871	247
	Scenario 2	–0.29%	0.71%	1.99%	0.10%	–2.82%
	Scenario 3	0.67%	–1.63%	–4.61%	–0.26%	6.90%
	Scenario 4	1.65%	–3.95%	–11.21%	–0.62%	17.78%
TWN	Scenario 1	385	2465266	2464881	3827	235
	Scenario 2	–0.12%	0.77%	0.77%	0.11%	–3.05%
	Scenario 3	0.29%	–1.79%	–1.79%	–0.37%	7.62%
	Scenario 4	0.76%	–4.41%	–4.41%	–0.79%	20.11%

Table 7　Changes for importing countries (continue)

Country or Area	Scenario	Production (metric tons)	Consumption (metric tons)	Trade Volume (metric tons)	Welfare ($ million)	Price ($)
MEX	Scenario 1	92583	4452549	4359966	5351	213
	Scenario 2	–0.36%	1.60%	1.64%	0.28%	–3.51%
	Scenario 3	0.72%	–3.12%	–3.20%	–0.57%	7.40%
	Scenario 4	1.77%	–7.48%	–7.68%	–1.45%	19.18%
FRA	Scenario 1	228635	1243963	1015328	1335	206
	Scenario 2	–0.37%	2.05%	2.59%	0.40%	–3.64%
	Scenario 3	0.66%	–3.52%	–4.46%	–0.72%	6.78%
	Scenario 4	1.83%	–9.42%	–11.96%	–2.05%	19.85%
USSR	Scenario 1	647899	755472	107574	873	210
	Scenario 2	–0.36%	1.16%	10.31%	0.26%	–3.56%
	Scenario 3	0.62%	1.94%	–17.33%	–0.46%	6.35%
	Scenario 4	–0.05%	0.17%	1.49%	0.04%	–0.52%
ENOE	Scenario 1	613034	950369	337335	1400	209
	Scenario 2	–0.36%	1.16%	3.94%	0.20%	–3.57%
	Scenario 3	0.62%	–1.95%	–6.61%	-0.34%	6.37%
	Scenario 4	2.03%	–6.21%	–21.18%	-1.18%	22.31%
SEA	Scenario 1	266651	5672654	5406003	9228	222
	Scenario 2	–0.34%	0.85%	0.91%	0.12%	–3.37%
	Scenario 3	0.59%	–1.43%	–1.53%	-0.20%	–6.01%
	Scenario 4	11.97%	–24.27%	–26.06%	-6.13%	209.62%
NWMA	Scenario 1	243932	568130	324198	1264	221
	Scenario 2	–0.34%	0.21%	0.62%	0.03%	–3.39%
	Scenario 3	0.65%	–0.39%	–1.17%	-0.07%	6.68%
	Scenario 4	1.71%	–1.01%	–3.06%	-0.19%	18.48%
NEMAF	Scenario 1	38219	369977	331757	543	216
	Scenario 2	–0.35%	1.10%	1.26%	0.16%	–3.47%
	Scenario 3	0.60%	–1.84%	–2.12%	-0.29%	6.19%
	Scenario 4	1.98%	–5.88%	–6.79%	-0.99%	21.67%
ROW	Scenario 1	NA	641891	641897	940	247
	Scenario 2	NA	1.29%	1.29%	0.20%	–2.88%
	Scenario 3	NA	–3.50%	–3.50%	-0.65%	8.48%
	Scenario 4	NA	–7.26%	–7.26%	-1.30%	18.76%
Total	Scenario 1	24818463	81942981	57124598	126490	225
	Scenario 2	–0.26%	1.15%	1.76%	0.17%	–3.27%
	Scenario 3	0.57%	–2.17%	–3.36%	-0.35%	6.59%
	Scenario 4	1.62%	–7.70%	–11.75%	-1.52%	40.63%

Note: NA means data is not available.

Table 8 Changes for exporting countries

Country or Area	Scenario	Production (metric tons)	Consumption (metric tons)	Trade volume (metric tons)	Welfare ($ million)	Price ($)
US	Scenario 1	79871023	48775439	31095583	45366	196
	Scenario 2	4.21%	2.32%	7.18%	0.39%	–3.82%
	Scenario 3	5.31%	–3.81%	19.62%	–1.49%	6.81%
	Scenario 4	0.26%	28.49%	–44.02%	2.03%	–34.65%
ARG	Scenario 1	32894163	28890828	4003334	29429	188
	Scenario 2	–0.27%	1.22%	–11.06%	0.33%	–2.70%
	Scenario 3	0.75%	–3.26%	29.69%	–0.90%	7.76%
	Scenario 4	1.93%	–8.15%	74.69%	–2.41%	21.12%
BRA	Scenario 1	47046138	27414349	19631789	28113	186
	Scenario 2	–0.41%	1.82%	–3.52%	0.50%	–4.01%
	Scenario 3	–5.04%	25.58%	–47.80%	4.09%	–40.40%
	Scenario 4	2.00%	–8.34%	16.44%	–2.59%	21.90%
INA	Scenario 1	4828804	4693887	134917	7415	202
	Scenario 2	–0.18%	0.45%	–22.02%	0.09%	–1.80%
	Scenario 3	0.37%	–0.89%	44.23%	–0.18%	3.72%
	Scenario 4	1.13%	–2.72%	135.01%	–0.57%	11.87%
LAM	Scenario 1	5273352	3014523	2259127	2521	123
	Scenario 2	–0.42%	1.35%	–2.78%	0.52%	–4.12%
	Scenario 3	0.80%	–2.52%	5.24%	–1.05%	8.35%
	Scenario 4	3.78%	–11.12%	23.65%	–12.78%	44.86%
Total	Scenario 1	170455700	113331200	57124816	113600	189
	Scenario 2	1.79%	1.80%	1.76%	0.38%	–3.63%
	Scenario 3	1.28%	3.61%	–3.36%	0.15%	–1.11%
	Scenario 4	1.20%	7.73%	–11.75%	–0.79%	0.79%

Note: NA means data is not available.

If the soybean world market is not a perfect competitive market, then the exporting country *i*'s market rent is $[a_j \eta_j (1 + A_{ij}) X_{ij}]$, while importing country *j*'s market rent is $[c_i \varepsilon_i (1 + B_{ij}) X_{ij}]$. This equilibrium condition indicates that the magnitudes of these price changes depend on export/import elasticity, trade volume, as well as export supply and import demand function.

Based on the definition of Scenario 4, $A_{US,j} = 0$, $B_{i,j} = -1$. So the price mark-up will depend on the term of $[a_j \eta_j X_{ij}]$. Since most of soybean importing volume for MYS, PHL, THA and SEA trading countries are from the U.S., and this is the reason to cause the higher price percentage change as compared with other importing regions.

However, when the exporters or the U.S. behave in an imperfectly competitive manner (i.e. Scenarios 3 and 4), the economic outcomes are reversed as compared with Scenario 2. If we take Japan as an example, production in Japan is seen to have increased while consumption and trading volume decrease with the import price sharply increasing by 19.43%. This tells us that as the U.S. resorts to imperfectly competitive trade tools, the welfare of the importers will decrease.

As soybean yields increase as a result of R&D increasing, the major exporters stand to benefit more. For instance, the U.S. obtains a larger trade surplus in Scenario 2 as shown in Table 8. Such estimates of welfare indicate that the increase in R&D expenditure on agriculture which causes the increase in yield of soybean will not only benefit the U.S. but will also help all other soybean exporting countries. That means that the U.S. may have the incentive to spill over the soybean-related biotechnology to other countries in order to further enhance its soybean yield. However, if the U.S. changes its marketing behavior from being a price-taker to becoming a Cournot-Nash player with the same percentage increase in soybean yield (i.e. Scenario 4), consumption and welfare in the U.S. will increase but production will decrease. The increase in welfare implies that the benefit from R&D will be greater in an imperfectly competitive market than in a perfectly competitive market. Such estimation results are consistent with the finding of Delbono and Denicolo (1991).

VI. Conclusions

A two-stage decision process involving R&D, trade and market power both in theory and in an empirical model is developed in this paper. This empirical model is applied to soybeans and the imperfect spatial equilibrium model using the conjectural variation approach is developed to determine the structure of the international soybean market. The empirical results show that the major soybean exporters are price-takers, while some of the import markets are characterized by imperfect competition. As the impacts of increasing R&D on soybean yields are incorporated into this empirical model, the empirical estimates show that both the importers and exporters benefit from this improvement in yields.

However, the economic outcomes may change as the players' behavior changes. The results of the estimation indicate that the greatest benefits accrue to the major exporters, which proves why larger exporters have the incentive to invest in R&D on crop yield improvement if the market is characterized by imperfect competition. From the theoretical and empirical analysis, it is seen that both the level of R&D and the market power affect the international soybean markets and the relationship between R&D and the market power is a two-way one. The major contribution of this paper is that we allow for varying degrees of market power through changes in the values of the conjectural variations in order to estimate the benefits of R&D on the world soybean market.

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市場力量和 R&D 對貿易福利之影響—以黃豆貿易市場爲例

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摘　要

本研究將以黃豆貿易市場爲例，利用兩階段決策過程來探討 R&D、貿易及市場力量之間在理論與實證上的雙向關係。我們利用不完全競爭空間均衡模型(imperfect spatial equilibrium model)結合猜測變量方法(conjectural variation approach)來探討因爲 R&D 所導致黃豆產出增加對國際黃豆市場的衝擊。實證數據支持主要的黃豆出口國皆屬價格接受者，而主要的進口市場則是不完全競爭市場。當 R&D 所導致黃豆產出增加時，不論進口國或是出口國皆增加貿易福利，然而貿易國家間的福利上升多寡則取決於該國的市場力量大小。

關鍵詞：R&D、市場力量、貿易、不完全競爭空間均衡模型

JEL 分類代號：Q13, Q16, Q17

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