Ex-ante Impact Assessment of GM-Papaya Adoption in Thailand[*]

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ABSTRACT

Despite the evidences of benefits from GM papayas adoption in other countries, concerns over the loss of export markets and health and environmental risks have led to great uncertainty and indecision about policies to support biotechnology in Thailand. Since 2001, field trials have been banned and the use of transgenic plants for production, consumption, or commercialization has been prohibited, but this ban is currently being reconsidered. This study estimates what the economic impact of the adoption of GM papaya would be if Thailand were to authorize the use of transgenic technology. We find that papaya farmers will benefit significantly from improved yields and even with no cost reduction.

Keywords: GM papaya, ex-ante assessment, Thailand

1. Introduction

Thailand was among the first Asian countries to recognize the benefits of agricultural biotechnology. The National Center for Genetic Engineering and Biotechnology (BIOTEC) was established in 1983. Since that time BIOTEC, together with the Department of Agriculture (DOA) and several universities, has conducted genetic engineering research. The Center for Agricultural Biotechnology (CAB) was established in 1999 through the collaboration of five academic institutions to enhance post-graduate study and to promote collaborative research in agricultural biotechnology. Although biotechnology was emphasized during the 6th National Social and Economic Development Plan (1987-1991), it has not been consistently supported, and policy constraints have increased.

The first field trial of transgenic plants in Thailand was Flavr Savr tomato in 1994 for seed production destined for export only. In 1996, field trials of Bt cotton were started but permission for the commercial release of Bt cotton has not occurred. In response to public protest concerning the widespread "contamination" caused by Bt cotton field trials, the Thai government on April 3, 2001 imposed a ban on all GE field trials until national biosafety regulation is implemented. Biosafety regulation has yet to be completed, even though work on a biosafety guideline began in June 1992. The Thai government is currently rethinking its policy on field trials of transgenic crops and has permitted field trials since December 25, 2007, but only by special request in government fields.

In 1999, the amendment of the 1964 Plant Quarantine Act strengthened the regulation to include all possible genetically modified plant varieties. On March 17, 2000, 40 transgenic varieties, with exceptions for grains of genetically modified corn and soybeans, were banned from importation. On October 14, 2003, an additional 49 transgenic varieties were listed as prohibited items for imports except for processed products.

There is little public information available on the costs and benefits of biotechnology to Thai economy and national policies and research and application plans are unclear. The economic evaluation of transgenic crops is essential to the development of appropriate future agricultural biotechnology policies. This study provides an ex-ante economic evaluation of the use of transgenic papaya in Thailand, since it is in the most advanced stage of development among GM crops. Implications from this study could be used to evaluate potential biotechnology policies in the future.

2. Development of GM papaya in Thailand

Papaya has traditionally been a staple crop in both the national diet and in the mixed cropping system of small farmers in Thailand. It is common for both green and ripe consumption and is a major ingredient in the daily diet in the Northeast. Thailand is a relatively small producer of papaya. In 2006, Thailand produced less than 2% of the world's papaya production, ranking as the world's 12th largest producer (FAOSTAT). The average yield during 2002-2006 was 2.42 ton/rai[1] having declined from 3.01 ton/rai during 1992-1996 (Table 1). The two most commonly grown varieties are Khakdam and Khaknuan. Most of the papaya production is consumed domestically. The exports of papaya are less than 2% of domestic production, and most exports are processed products rather than fresh produce. Seventy four percent of total papaya exports quantity was canned, valued at 84% of total papaya exports (The Custom Department, 2006).

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[1] 1 hectare = 6.25 rai

Table 1. Papaya production and prices in Thailand, 1988-2007

Year	Production area (rai)		Total production (ton)	Average yield (ton/rai)		Price (THB/kg)
	Planted	Harvested		Planted	Harvested	
1988	112,653	70,457	201,918	1.79	2.87	3.49
1989	106,964	63,514	182,120	1.70	2.87	4.01
1990	165,812	114,275	376,525	2.27	3.30	4.16
1991	159,886	113,448	339,096	2.12	2.99	3.89
1992	149,228	108,183	346,305	2.32	3.20	3.83
1993	152,796	116,343	363,579	2.38	3.13	3.92
1994	161,552	123,600	367,987	2.28	2.98	3.98
1995	153,280	115,572	342,772	2.24	2.97	4.38
1996	160,241	119,725	335,433	2.09	2.80	4.41
Avg. 1992-96	155,419	116,685	351,215	2.26	3.01	4.10
1997	153,060	118,051	316,879	2.07	2.68	5.25
1998	172,793	118,938	367,861	2.13	3.09	5.43
1999	187,648	138,504	412,138	2.20	2.98	4.87
2000	155,959	126,422	366,828	2.35	2.90	5.11
2001	146,248	102,044	290,854	1.99	2.85	5.04
Avg. 1997-01	163,142	120,792	350,912	2.15	2.90	5.14
2002	147,953	118,539	351,693	2.38	2.97	3.89
2003	140,696	108,974	309,003	2.20	2.84	4.96
2004	127,343	100,480	277,923	2.18	2.77	5.69
2005	55,122	34,588	30,961	0.56	0.90	5.89
2006	83,612	51,067	134,443	1.61	2.63	6.98
Avg. 2002-06	110,945	82,730	220,805	1.79	2.42	5.48
2007	104,968	72,554	195,377	1.86	2.69	9.00
Growth rate 1997-06	-0.45	-0.57	-0.58	-0.22	-0.02	0.33

Note: 1 hectare = 6.25 rai

Source: Department of Agricultural Extension, 2007

Angyurekul and Tugsinavisuth (2003) analyzed the papaya industry during 1988-2001 and found that one of the most important problems was the infestation of Papaya Ring Spot Virus (PRSV), and one of the greatest threats to the industry was the the lack of research and development of PRSV resistant varieties. Since PRSV was discovered in Northeastern Thailand in 1975, it has spread throughout the country. Papaya area and production fell by more than one-half between 1997 and 2006, and Thailand has changed from being a small exporter to being an importer of papaya from neighboring countries.

Several attempts have been initiated to develop PRSV resistant papaya. In 1987, a research team at the Horticultural Research Institute, Khon Kaen Agricultural Research Station of DOA bred a tolerant variety by crossing the “Florida tolerant” variety with Khakdam. By 1994, three lines of PRSV resistant hybrids, Thapra 1, 2, and 3 were developed, providing average yields of 10.624 ton/rai. Up to 2004 Thapra 2 (renamed to “Khakdam Thapra”) was the primary variety recommended by DOA and was distributed to 37 provinces in the northeast and other regions. This variety is partially resistant to PRSV. Therefore, after planting it for a while or if planted in an infested area, it could still eventually become infected (U.S. Department of Agriculture, 2005). Currently, no papaya seeds are distributed to farmers by the Northeast Regional Office of Agriculture (NEROA), due to as of yet unsubstantiated accusations that the station allowed genetically modified seeds to escape the confines of the station.

GM PRSV resistant was successfully developed by the collaboration between Thailand DOA and Cornell University in 1995. In 1997, the research team returned to Thailand with two transformed varieties, Khakdam and Khaknuan, which were transferred to the research station at Thapra, Khon Kaen province for further breeding and analysis in the confines of a greenhouse. Field trials began at the station in 1999 and continued until 2004. Selected third generation lines from both transformed varieties showed 97-100% resistance to the virus (Davidson, 2006) and providing an average yield of 11.81 ton/rai (U.S. Department of Agriculture, 2005). On July 27, 2004, Green Peace sealed off an experimental field of GM papaya at Khon Kaen Agricultural Research Station and demanded that the government immediately destroy all papaya trees, fruit, seedlings, and seeds in the Khon Kaen research station to prevent further contamination. They claimed that tests conducted by GeneScan (HongKong) Ltd. found the contamination of GM papaya in farmers' fields despite the Plant Quarantine Act.

In addition to the research done by DOA, two other projects have been intiated to create GM PRSV resistant papaya. The first one was under Papaya Biotechnology Network (PBN) of Southeast Asia which was supported locally by BIOTEC and and the Plant Genetic Engineering Unit (PGEU) at Kasetsart University, Kamphangsan campus. The GM PRSV resistant vareity was sucessfully developed in work dating to 1997. Plant materials from Queensland University, Australia were twice brought in for the purpose of conducting research to create resistance to ring spot virus, and to extend the ripening period. The first time was in August 1998, and second time was in May 2000. A field trial was ongoing at PGEU until 2004 when the moratorium on field testing of GE crops was put in place in Thailand. The other was done at Institute of Molecular Biology and Genetics at Mahidol University. The project started in 1994.

3. Economic Evaluation of GM Papaya

Although several studies have evaluated the economic impacts of GM crops, only a few were of GM papaya. Gonsalves *et al*. (2004)

conducted a farmer survey during June–September 1999 in Puna area of Hawaii. They found that the adoption of Rainbow PRSV resistant variety was at 76% during May 1998-September 1999. Sankula and Blumenthal (2004) estimated the benefit of PRSV resistant papaya in Hawaii by comparing the annual data to 1998 base year when it first became available. They found that the yield increase ranged from 16-77%, production value increased from 1.14-5.54 million USD during 1999-2003, and there was no cost saving benefit. Brookes and Barfoot (2006) summarized the benefits of GM crops in different countries. By reviewing the studies by Sankula and Blumenthan in latter years (2003 and 2005), they found that GM PRSV resistant papaya could provide 16-50% of yield improvement during 1999-2005. There was no cost to farmers for acquiring the technology during 1999-2003, but since 2004, the cost increased to 42 USD/hectare.

The Foreign Agricultural Service in Thailand (U.S. Department of Agriculture, 2005) evaluated economic benefits of PRSV resistant GM papaya in Thailand by collecting primary data from 122 farmers, 83 villagers, 20 collectors and wholesalers, 41 restaurant owners, 18 manufacturers and exporters, and from depth interviews of 11 government officers, lecturers, and researchers. This study assumed that the yield will improve from 2.79 to 42 ton/rai if farmers were to adopt GM papaya. These numbers were obtained by interview with Mr. Chakan Sangruksawong, the general director of DOA, who claimed that the average yield of papayas nation-wide decreased by 50% to 2.79 ton/rai due to PRSV infestation.

Based on five different regions, five types of plantation, and types of fruits at the time of sales (green or ripe), the study compared farmer's income from growing GM *vs* non-GM variety. The estimate of average gross income across regions after adopting GM papaya was

228,900 THB/rai/crop compared to 15,097 THB/rai/crop of non-GM variety. The difference in benefits of GM papaya is greater if grown in open space in mixed plantation and selling it ripe. The estimate of net income over total initial investment of GM papaya would be 307,099 THB/rai/crop, compared to 13,911 THB/rai/crop for the non-GM variety. This study assumes that the price of GM papaya is the same as the price of non-GM.

All of the above studies have estimated the farm-level impacts from adopting GM papaya, mainly farm income effects, by comparing costs and benefits of two alternative varieties each year. However, they did not take into account the impact on equilibrium price, did not cover the welfare distribution effect, and did not take into account the impact over time. Thus, it does not represent total economic effects. Since there is no commercial GM crop grown in Thailand, this study uses the ex-ante analysis by making assumptions based on scientific data and economic environment in Thailand, and evidences from studies in other countries. The economic impact of GM papaya is measured by using the concept of economic surplus which could reflect the aggregate impact to the country as a whole. The analysis also considers the rate and the time of adoption, and estimates the present value of the impact during the study period.

4. Theoretical Framework

Alston *et al*. (1998) suggested several approaches to evaluate agricultural technology. This paper measures the impacts of GM papaya using the economic surplus model. Despite several criticisms of the economic surplus measurement including measurement errors, general equilibrium effects, ignoring transaction costs and externalities, it is still justified when appropriate assumptions about impacts of research are being made. The economic surplus model is also more advantageous than cost-benefit analysis and economometric models since it does not assume either perfectly inelastic or perfectly elastic supply or demand (Alston *et al*., 1998: 54-55). In addition, the economic surplus calculation incorporates international price effects and distributional effects unlike the cost-benefit analysis. For the ex-ante analysis in this paper, a partial equilibrium model is adopted due to the limitation of information on dynamic linkages between sectors.

Since Thailand is a small producer and exporter of papayas, a small open exporting economy model is assumed. Figure 1 illustrates the changes in economic surplus from the adoption of GM papayas in a small exporting country. GM papaya will improve the yield whereas the cost of chemicals is assumed to remain constant. This results in the downward shift of supply curve from S_0 to S_1, and the domestic demand curve of papayas is assumed to be constant. The price of papaya is determined by the world market at P_w, and will not change because of the increasing supply in Thailand. Consumer surplus, thus, remains constant; whereas, producer surplus increases equal to the area "abcd". In this case, Thailand could increase its export to "$Q_1 - Q_0$" if GM papaya is accepted in the export markets.

In this analytical framework, the domestic market is assumed to be homogeneous. In other words, consumers cannot distinguish between GM and non-GM papayas. Even though labeling is required for GM products[2], but it only covers soybeans and maize, and does not cover products sold by small vendors. Fresh papaya is commonly sold in fresh markets by small vendors or sold as prepared

[2] The Minister of Health announcement in 2002 of the GM labeling regulation requires that foods containing ingredients derived from GM soybeans and maize in the top three components by weight representing more than 5% of the total weight and have more than 5% GM of each ingredient must be labeled.

dishes by food stalls or restaurants so the labeling regulation will not be able to identify GM papaya sold in the domestic market.

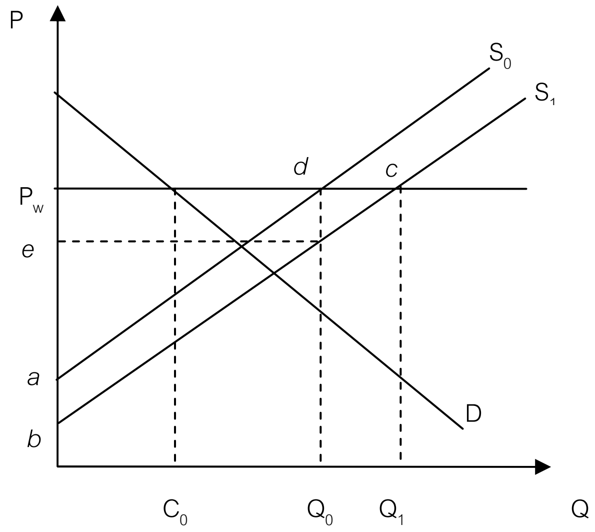

Figure 1. Changes in economic surplus from GM papaya adoption in a small exporting country.
Source: Adopted from Alston *et al*. (1998: 227)

It is also assumed that lost of export market is immaterial in this framework since most of papaya is consumed domestically. In addition, the largest export market of papaya from Thailand is China (accounted for over 90% of total papaya exports) does not oppose to GM products.

5. Methodology

To measure the change in producer surplus, abcd, in Figure 1, the calculation is adapted from Alston *et al*. (1998: 380-383) as follows:

$$\Delta PS = \Delta TS = P_W Q_0 K(1 + 0.5K\varepsilon) \quad (1)$$

where PS is the producer surplus
TS is the total surplus
P_w is the world price
K is the proportional supply shift = $(P_w - e)/P_w$
ε is the supply elasticity

Using the spreadsheet to calculate annual surplus, it is assumed that

$$K_t = \left[\frac{E(Y)}{\varepsilon} - \frac{E(C)}{1 + E(Y)} \right] pA_t(1 - \delta_t) \quad (2)$$

where K_t is the proportionate shift down in the supply curve in period t due to GM papaya adoption.
E(Y) is the expected proportionate yield change per rai.
E(C) is the proportionate change in variable input costs per rai to achieve the expected yield change.
p is the success rate or the probability that GM papaya will achieve the expected yield.
A_t is the adoption rate (proportional area of GM papaya to total papaya production area in year t).
δ_t is the rate of annual depreciation of GM papaya (reduction of expected yield) in year t.

In this framework, the impacts are assumed to accrue for ten years after first adoption, which takes place in year three. The net present value (NPV) is calculated from the annual surplus as follows:

$$NPV = \sum_{t=0}^{T} \frac{\Delta TS_t}{(1+r)^t} \quad (3)$$

where r is the discount factor.

Parameter assumptions are based on experiment/scientific studies of GM papaya in Thailand and in other countries. The technology adoption and economic environment assumptions are based on secondary information for Thailand. It is assumed that the success rate of GM papaya production is perfect (p=1). In other words, if farmers adopt GM papaya, they are guaranteed to achieve expected yield, and there is no yield reduction after each crop ($\delta_t = 0$). The discount factor is assumed to be at 5%.

The assumptions for this analysis are summarized in Table 2. Because Thailand is a small exporting country, farm price is assumed to be equal to the world price. The average farm price between 2002-2006 was 5,482 THB/ton (Department of Agricultural Extension, 2007). The area of production between 2002-2006 was 110,945 rai. Assuming that the potential yield of GM papaya equals to Khakdam Thapra, which has the PRSV resistant characteristic and was recommended by the Department of Agricultural Extension, to be 10.624 ton/rai (Prasartsri and Chaikietiyod, no date); whereas, the average yield of general papaya during 2002-2006 was 1.785 ton/rai (Department of Agricultural Extension, 2007), the yield of GM papaya improves by 495%. The cost of production will not change since most current papaya growers do not generally use either pesticides or herbicides. The costs of GM and non-GM seeds are assumed to be the same. This is because the proportional cost of seed is minimal, and the government is expected to distribute GM seeds; thus, there is no technology fee or seed premium.

Table 2. Assumptions of parameters used

Average total production area, 2002-2006 (rai)	110,945*
Average production, 2002-2006, Q_0 (mt)	220,805*
Average farm price, 2000-2003, P_w (THB/mt)	5,482*
Average total value of crop (THB/mt)	1,210,453,010
Expected GM papaya yield (kg/rai)	10.624
Average current yield, 2002-2006 (kg/rai)	1.785*
% Yield increase, E(Y)	496
% Cost reduction, E(C)	0
Supply elasticity, ε	1
Adoption ceiling (% area)	80
Adoption lag (years)	3
Years to full adoption	10

Source: * Department of agricultural extension, 2007

A three year lag to initial adoption from the date GM papaya is permitted will be assumed. GM papaya varieties are almost ready to be used, but still need to pass biosafety field testing, and may take some time for seed propagation. A ceiling adoption level of 80% is assumed to be achieved within ten years. The incremental increase of the area of GM papaya adoption is assumed to be the same each year. Results are presented for total papaya production area under two scenarios. In the first scenario, the production area is assumed to be equal to current average production area during 2002-2006 (110,945 rai). Under the second scenario, production area is assumed to the higher area that existed during 1997-2001 (163,142 rai) when the PRSV infestation was less severe. In this scenario, the adoption ceiling is also assumed at 80%, and the adoption area increases equally from year 4 to year 13 from 110,945 to 163,142 rai.

6. Results

The estimates of welfare impacts are presented in Table 3. Under scenario 1, the model suggests that GM papaya will be generating about USD 413 million, or nearly 13 billion THB in annual benefits by the time of full adoption, in year 13 and will generate a total discounted value of USD 1,098 million or 34 billion THB. In the second scenario, where it is assumed that the total papaya area returns to the 1997-2001 average area, the total discounted economic surplus is estimated at USD 1,456 million (45 billion THB).

Table 3. Economic surplus of GM papaya adoption

Year	% of area adoption	Total surplus			
		Scenario 1 Total area = 110,945 rai (17,751 ha)		**Scenario 2** Total area = 163,142 rai (26,103 ha)	
		(million THB)	(USD)	(million THB)	(USD)
0	0	0	0	0	0
1	0	0	0	0	0
2	0	0	0	0	0
3	0	0	0	0	0
4	8	515.26	16.62	515.26	16.62
5	16	1,200.88	38.74	1,263.66	40.76
6	24	2,056.88	66.35	2,271.93	73.29
7	32	3,083.25	99.46	3,566.78	115.06
8	40	4,279.99	138.06	5,174.93	166.93
9	48	5,647.10	182.16	7,123.10	229.78
10	56	7,184.58	231.76	9,438.01	304.45
11	64	8,892.43	286.85	12,146.37	391.82
12	72	10,770.65	347.44	15,274.91	492.74
13	80	12,819.24	413.52	18,850.34	608.08
NPV (5% discount rate)		34,033.68	1,097.86	45,136.64	1,456.02

Note: 1 USD = 31 THB

7. Conclusions

This study estimates benefit for GM-PRSV resistant papaya. The papaya industry has been severely affected by PRSV, with national production in 2007 falling to half of its level in 1999. Adapted transgenic papaya varieties have been developed, suggesting that seeds could be made available to farmers within a relatively short time. Informal evidence suggests that farmers in Thailand would be willing to adopt GM varieties once they are commercially available. GM crops have already provided large economic benefits in several countries of the world, and hold great promise for delivering large benefits in Thailand once biosafety protocols are established. If Thailand is able to return its papaya industry to the size that they had a decade ago, and if GM varieties are successful, Thailand stands to reap economic benefits of more than a billion dollars. The majority of these benefits would accrue to small farmers.

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