An Economic-wide Analysis of GM Food Labeling Policies in Taiwan

Shih-Hsun Hsu, Ching-Cheng Chang and Chia-Hsuan Wu *

Abstract

The development of agricultural biotechnology offers the opportunity to increase crop production, lowers farming costs, improves food quality and could reduce costs to consumers. Until now Taiwan haven't commercialized any genetically modified (GM) crops. However, Taiwan imports a large amount of grain products for human consumption and animal feed processing from the world market annually. The import quantities as well as prices will be affected through world market as the production technology of GM crops is adopted by the exporting countries. Many sectors have been affected by the use of these crops through vertical (or backward) and horizontal (or forward) linkages.

This paper offers a quantitative assessment of the economic impacts of importing GM crops on Taiwan's economy. A multi-sectoral computable general equilibrium model is used. This model is amended by splitting corn and soybeans into GM and non-GM varieties. It also endogenizes the decision of producers and consumers to use GM vs. non-GM corn and soybeans in their intermediate uses and consumption, respectively. The choice between GM and non-GM varieties is determined by a CES function. We also consider the consumers' acceptance of GM food so that the mandatory labeling policy can be examined. Our simulation results indicate that the most extreme import ban on GM crops would be very costly in terms of total production values, ranging from NT$ 40 to 90 billions per year.

Keywords: Computable General Equilibrium (CGE) Model, Genetically Modified Crops (GM crops), Labeling

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An Economic Analysis of GM Crops on Taiwan's Agriculture

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1. Introduction

The new agricultural biotechnologies that are generating transgenic or genetically modified (GM) organisms are getting increasing attentions in recent years. Among all major agricultural technology innovations, biotechnology is by all means the most controversial due to in part the prevailing uncertainty and concerns raised by many for its biosafety and environmental impacts. The rise of modern biotechnologies and life sciences have brought with them many surprises and may change the paradigms of the society and revolutionize our daily lives (Ku, 2002). It is very important to bear in mind that all technologies, bio and non-bio, are to serve the ultimate objective of improving the overall welfare of human beings and the nature. Agricultural biotechnology is no exception.

Until now Taiwan haven't commercialized any GM crops. However, Taiwan used to be highly dependent on importing lots of grain products from the world market. The import quantity as well as price will be affected through the world market as production technology of GM crops is adopted by exporting countries. When the GM crops are imported to Taiwan as inputs for many agricultural and food products, other sectors will also be affected by the use of GM crops through vertical (or backward) and horizontal (or forward) linkages.

This paper offers a preliminary quantitative assessment of the economic impacts of Taiwan's GM crops (mainly soybeans and corn) importation on the overall economy. To serve this purpose, a multi-sectoral computable general equilibrium model is used, named ORANI Model. This model is amended by splitting soybeans and corn into GM and non-GM varieties. It also endogenizes the decision of producers and consumers to use GM vs. non-GM corn and soybeans in their intermediate processing and consumption, respectively. The choices between GM and non-GM varieties are determined by a CES function. We also consider the consumers' acceptance of GM food so that the mandatory labeling policy can be examined.

The paper is organized as the follows. In the next section, a general review about the production and trade situation of GM soybeans and GM corn in Taiwan is provided. The third section presents the model and scenarios that will be used in the impact assessments. The impacts of alternative GM soybeans and GM corn policy strategies will be discussed in the fourth section. The final section provides concluding remarks and suggestions for policy actions.

2. GM crops development

Because world trade statistics does not provide any information on GM soybean and GM corn, we have to create some rough estimates based on production and export information. In this section, we will first review the world production and export statistics on GM soybeans and corn. After this, we can provide an estimation on the proportion of GM soybeans and corn imported in Taiwan.

2.1 World production

Around the world, there were virtually no GM crops in the field before the 1990s. Nowadays, the estimated global area of transgenic or GM crops for 2001 is already 52.6 million hectares in 13 countries (ISAAA, 2002). The increase between 2000 and 2001 was 8.4 million hectares and represents a 19% increase. Between 1996 and 2001, the total area of GM crops grew about 30 times.

Geographically speaking, production of GM crops is currently concentrated in just a few countries while more countries are experimenting new traits. For 2001, 99% of GM crops are produced in four countries, namely US (68%), Argentina (11.8%), Canada (6%) and China (3%). In crop-wise, GM soybean is the most popular one, accounting for more than 60% of global area. GM corn comes next, accounting for 19% (ISAAA, 2002). The same report also indicated that the two major GM traits in 2001 were herbicide tolerant crops, accounted for 77% of all GM crops, while Bt maize accounted for 11%.

In terms of trade, it is obvious that the world's top three GM crop producing countries are all major agriculture exporters, i.e., the U.S., Canada and Argentina.

China's is growing very fast in GM crop production but mostly for domestic consumption (Huang et al, 2002). The majority of GM agricultural products in trade concentrate in crops. This section will attempt to estimate the global trade volume using data available from various sources with GM soybean and GM corn as examples.

Although the estimated global planting acreage of GM crops is around 52.6 million hectares as stated previously in this paper, there is yet no available statistics on the amount of the global GM product in trade. However, it is possible to estimate the trade volume of GM products with information available from various sources. A compilation of data is presented as follows.

2.2 GM soybean export

The 2000/2001 global trade volume of soybean has reached 54.88 million metric tons (mt). The top three exporters were U.S. (49.4%), Brazil (27.5%), and Argentina (13%) (USDA, 2002). These top three GM soybean growing countries exhibit similar trade patterns. U.S. exports about 36% of its soybean production, followed by Canada's 33% and Argentina's 27% (compiled from USDA, 2002).

ISAAA (2002) data indicated that, in 2001, GM soybean made up 46% of global soybean planting areas. Statistics from USDA (2002) showed that the global production of soybean was 174.94 million tons in 2002. Before converting planting acreage into production volume, difference in productivity must be taken into account. Drawing from the findings of a Canadian study, Hategekimana (2002) reported that preliminary results showed that GM soybean had a productivity about 3% to 4% higher than conventional soybean. Shoemaker (2001) on the other hand, reported a yield difference between 1% and 5%. With these information, a simple mathematical average of 4% is therefore used to calculate the shares of GM and non-GM soybeans of the global production. As estimated by this study, in 2001, GM and non-GM soybeans production were about 84 million mt and 92 million mt, respectively. The ratio of tonnage between GM and non-GM soybeans is therefore 47.5% to 52.5%. The GM percentage is slightly higher than ISAAA's 2002 figure of 46%.

Assuming that GM and non-GM soybeans have an equal opportunity (or probability) of being exported, the trading volume of GM soybean can be approximated. Once again, using USDA (2002) statistics, the global soybean trade amounted to 54.88 million mt in 2001. If we accept the assumption of equally probability of export, then the estimated global GM soybean trade volume of 26 million mt can be obtained. In percentage term, 47.5% of soybean globally traded belongs to GM variety.

Among the three major soybeans exporting countries, Argentina is worth noticing. After taking the productivity factor into account, over 98% of soybean harvested was GM variety. Consequently, Argentina exported about 13% of the global soybean trade volume. As for the world's largest soybean exporter U.S., NASS (2002) reported a GM share of 74 percent in acreage, which can be converted into 77% of production. Again, assuming equal probability of export, an estimate around 21 million mt of GM soybean were exported by the U.S. Therefore, the U.S. and Argentina together accounts for roughly half of global soybean trade volume.

2.3 GM corn export

In the case of corn, productivity varies greatly. Hategekimana (2002) reported a range between 4% and 12% higher than traditional corn production. Monsanto (2002) reported a discrepancy of 13.1 bushels per acre. Compared the 13.1 bushels up to 119 bushels per acre differences during period 1990~1995, this may translate into a roughly 11% increase (Dittrich, 2002). Taking the simple mathematical average of these reports, a 9.5% yield difference is used in the calculation of trade volume.

ISAAA (2002) reported that biotechnology varieties made up 19% of global corn planting area. The USDA (2002) statistics indicated a global production of 585.69 million tons. With the difference in unit yield, it can be estimated that total world production can be divided into to a GM portion of 20% and a non-GM portion of 80%, which translates into around 117 million mt of GM corn and 469 million mt of non-GM corn, respectively.

World's top three corn exporters of 2001 were U.S. (64%), Argentina (15%) and China (9.6%) (USDA, 2002). Again, assuming GM and non-GM corn have equal probability to be exported, this number suggests that at least 1.7 million mt of GM corn are exported by Argentina. U.S. farmers planted 26% of cornfield with GM varieties in 2001 (NASS, 2002), doubling that of Argentina. Using the same calculation, it can be estimated that around 28% of U.S. corn export is GM variety, which in absolute terms is about 14 million mt.

2.4 Taiwan's import of GM crops

In Taiwan, soybean and corn are mainly imported for human consumption and animal feed processing. According to the latest Input-Output Table (1999) published by Directorate General of Budget Accounting and Statistics Executive Yuan, R.O.C, the total domestic output value of Taiwan's soybean was 9 million N.T. dollars, which are all non-GM variety. In the same year Taiwan imported 16.8 billion N.T. dollars of soybean. If we consider the previous estimation of GM soybean export proportion, approximately half of them should be GM soybeans.

As for corn, the domestic output value in 1999 was 3 billion N.T. dollars, which are all non-GM corn. The import value of corn was 17.2 billion N.T. dollars. Based on the GM export proportion calculated in the previously subsection, about 30% should be GM corn and the rest be non-GM.

A majority part of soybean and corn imported flows into the processing sectors. They would be used in animal feeds, oil and fats, dairy products, or other processed foods. Information on any number of the attributes of GM food product can be recorded and passed along the food marketing chain. GM foods nowadays are coming to the market. Over the past few years, food biotechnology and safety has received increasing attentions in Taiwan.

2.4 Taiwan's Policy for GM foods

In the production side, Taiwan government has put the priority on maximizing the impact of the new agro-biotechnology at the farm level. Public awareness, food safety and intellectual property rights are equally respected. Knowledge of basic research on agro-biotechnology is considered an issue of the public domain. In this regard, the government takes the initiative in research and development of biotechnology. Research findings with potentials for further applications are transferred to the private sectors and farmers through various extension channels.

As for the GM food consumption, a voluntary labeling of GM food has been introduced by Department of Health in Taiwan from 1 January 2001, while mandatory labeling of designated foods will be introduced in three stages according to degree of processing of the food products starting from January 2003. Under the new labeling requirement, food containing more than 5% of GM soybean or corn in the finished product has to be labeled. On the other hand, food containing less than 5% of GM soybean or corn is regarded as "non-GM ingredient". Thus, Taiwan's labeling policy only designates toward food containing GM ingredients.

3. CGE Model and Scenarios

The modeling framework used in this analysis is a multi-sectoral computable general equilibrium (CGE) model of the Taiwan's economy derived from ORANI model (Dixon, Parmenter, Sutton and Vincent, 1982). The input-output database was compiled from the 160-sector Input-Output tables of 1999. The model distinguishes 160 sectors, 6 types of labor, 8 types of margins and 160 commodities. It is designed for conducting comparative static analysis, i.e., for projecting the impact of an external shock on the economy at a point in time.

3.1 Model structure

First, on the supply side, the CGE model allows each industry to produce several commodities, using domestically produced inputs, imported materials, labor of several types, land, capital, energy of several types, and "other costs". Commodities destined for exports are distinguished from those for local use. The multi-input, multi-output production specification is kept manageable by a series of separability assumptions.

Cost-minimization behavior by producers is assumed, implying that each factor is demanded so that marginal revenue product equals marginal cost, given that all factors are free to adjust. The input demand of industry production is formulated by a five-level nested structure, and the production decision-making of each level is independent. The first level depicts the labor composition based on a constant elasticity of substitution (CES) function of various types of vocations. It also contains the aggregation of intermediate inputs from domestic and imported inputs by using a CES aggregation function. The second level describes the composition of primary input from labor, land, capital, and other inputs. It is also aggregated under the CES type of specifications.

At the third level, the commodity composition are specified as a Leontief production function of primary inputs and other intermediate inputs. Consequently, they are all demanded in direct proportion to the industry activity at the fourth level. At the fifth level, each commodity is allocated into the domestic and export market governed by constant elasticity of transformation (CET) transformation frontier.

On the demand side, the model assumes that the utility function takes the nested form. Households act as price takers and maximize their utility functions subject to budget constraints. The form of the household's utility functions is the Klein-Rubin function, also known as the Linear Expenditure System (LES) function. In the LES function, there is substitution between different goods, and the goods are a composite CES aggregation of domestic goods and imported goods.

3.2 Model extensions

The model is amended in three steps. First, we separate soybeans and corn from the crops sectors. Next, we split the soybeans, corn, and their corresponding processing sectors into GM and non-GM foods. Thereby, we allow for a choice between GM and non-GM in production and consumption.

In the model we endogenize the decision of producers and consumers in adopting GM vs. non-GM varieties in their production and final demand. Intermediate demands for each composite commodities (i.e., GM plus non-GM) are held fixed as proportions of outputs by using a Leontief production function specification. By doing so, the initial input-output coefficients remain fixed, but for GM-potential varieties, a choice is introduced between GM and non-GM varieties. The choice between GM and non-GM varieties is determined by a CES function with a certain degree of substitution possibilities. Other intermediate input demands remain in fixed proportions in relating to their output. Figure 1 illustrates our nested structure. In our empirical analysis, the input-output choice is endogenized for four sectors, i.e., "Edible oil and fat"; "Feeds"; "Processing foods", and "Livestock".

Similarly, final consumption of each composite good will be an endogenous choice between GM and non-GM varieties for GM-potential commodities. We allow for substitutions among different goods. The GM-potential goods are composted under a two-layer system. The first layer is a composition of domestic and imported goods and the second one a CES aggregation of GM goods and non-GM goods. Non-GM goods have a simpler aggregation structure and are composed of imported and domestic goods. Figure 2 depicts the choice between GM and non-GM varieties in final consumption.

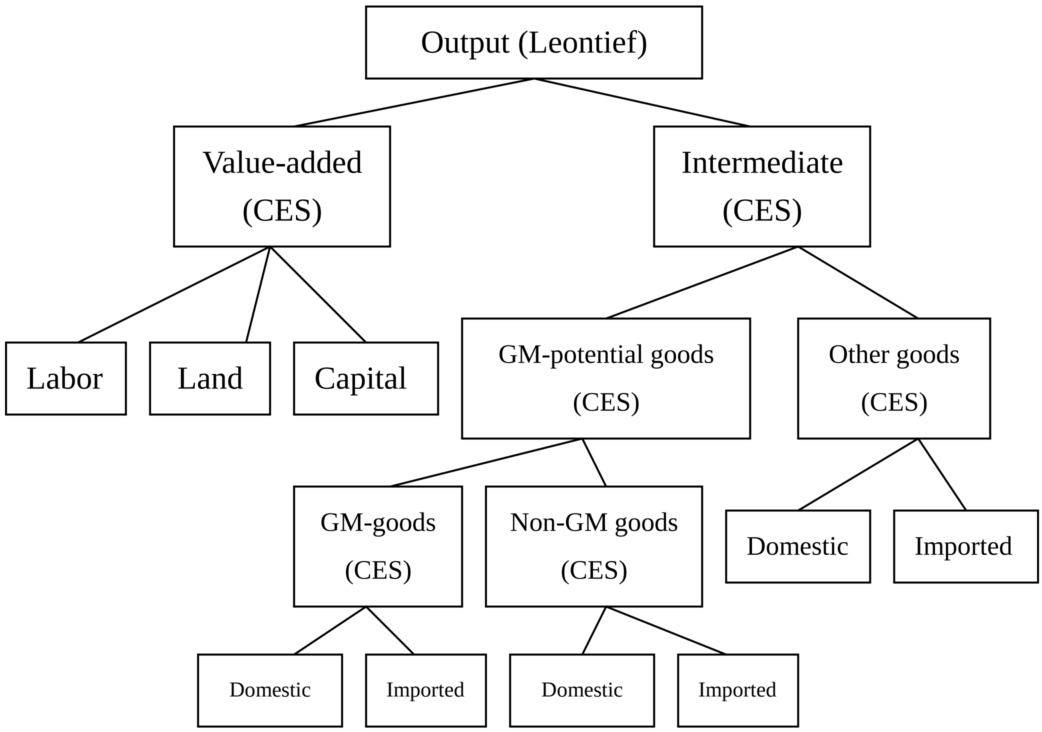

Figure 1. GM vs. non-GM choice in intermediate demand

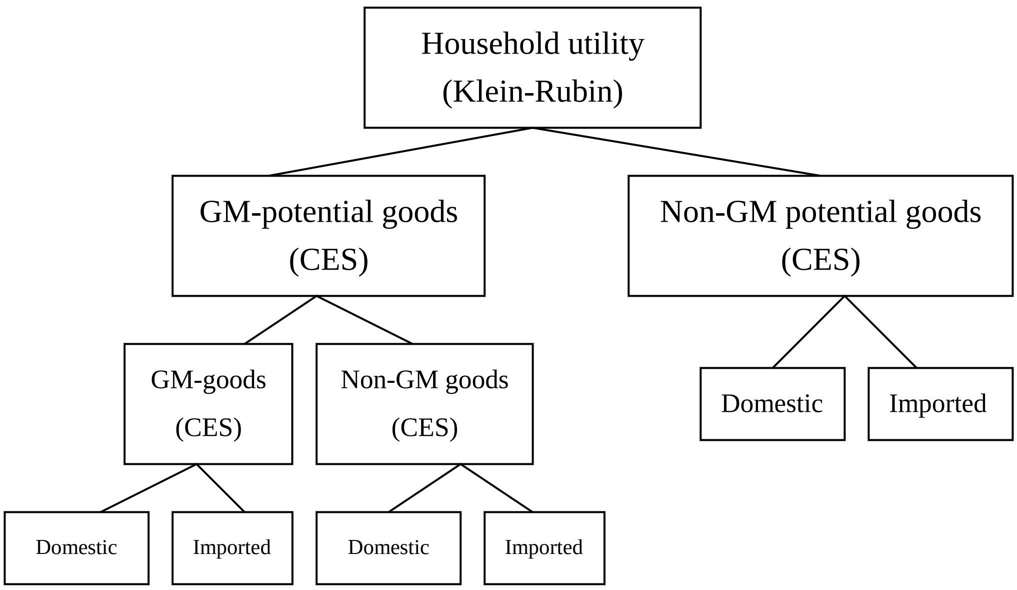

Figure 2. GM vs. non-GM choice in final demand

In summary, the salient feature of our extended model is that the decision of producers to use GM or non-GM varieties in production and processing are endogenized in our model. Similarly, final consumption of each composite GM-potential good is also an endogenous choice between GM and non-GM varieties.

3. 3 Data specification

The model used in our empirical study is divided into 18 sectors, which includes 7 primary agriculture sectors (paddy rice, other crops, other special and horticultural crops, livestock, agricultural services, forestry, and fish) and 4 food processing sectors (edible oil and fat, animal feeds, food products, and beverages). The remaining 7 non-agricultural sectors are respectively the energy and mineral products, leather products, lumber and by-products, chemical industry, other industry products, transportation, and services. The data is based on the 1999 Input-Output Table published by the Directorate General of Budget Accounting and Statistics Executive Yuan.

Table 1 provides the share of GM soybean and corn in GM-potential food production. First, we separate the source of supply into domestic and imports. In the domestic part, the shares of GM soybean and GM corn are zeros because there is no GM soybean and GM corn production in Taiwan. In import part, the shares of GM soybean and GM corn are 50% and 30%, respectively. After converting to the proportion with the imported value of the other crops, the shares of GM soybean and GM corn in imported other crops are 19.21% and 12.05%.

Next, in the food processing sectors, the oil and fats sector used 14.63 billion million NT dollars of soybean and corn in processing. Among them, 14.2 billion NT dollars came from soybeans. Since 50% are assumed to be of GM varieties, there are approximately 71.13 billion NT dollars of GM soybean being processed in this sector. The remaining 0.4 billion NT dollars came from corn and 30% are GM-varieties. So approximately 0.122 billion NT dollars of GM corn are processed each year. This amounts to the average share of 49.45% [i.e., (71.13%+1.22%) /146.3 % = 49.45%] for GM products in the oil and fats sector. The estimation is the same for all other food processing sectors.

Table 1. Estimated shares of GM varieties in GM-potential food production

Sector	Sub-sectors	Shares	Commodities contained in the Input-Output Table
Other crops	Domestic:		Crops excluding paddy rice
	GM bean	0 %	
	Non-GM bean	0.1%	
	GM corn	0 %	
	Non-GM corn	34.48%	
	Other crops	65.42%	
	Imported:		
	GM bean	19.21%	
	Non-GM bean	19.21%	
	GM corn	12.05%	
	Non-GM corn	28.13%	
	Other crops	21.40%	
Livestock	GM	31.82%	Hogs, other livestock,
	Non-GM	68.18%	Slaughtering and by-products
Edible oil and fat	GM	49.45%	Edible oil and fat
	Non-GM	50.55%	
Feeds	GM	31.82%	Feeds
	Non-GM	68.18%	
Processed foods	GM	39.81%	Flour; rice; Sugar; Canned food; Frozen food; Monosodium glutamate; Seasonings; Ddiry products; Sugar confectionery and bakery products; Miscellaneous food products.
	Non-GM	60.19%	

Source：Estimated from 1999 Taiwan IO tables with 596 sub-sectors.

3.4 Simulation design

Before conducting our simulation, we need to update the database from 1999 to 2002 in two aspects. First, we update the macro economic indicator, such as GDP, consumption, investment, and government expenditure. Second, we need to differentiate the prices of food products between GM and non-GM varieties. We amended the domestic price of GM varieties according to Hsu et al. (2000) that Taiwan's corn and soybean prices would, respectively, reduce by 14.55% and 3.2% once GM soybean and GM corn are imported.

Three policy scenarios are simulated based on our updated model for 2002. They are described as follows:

Scenario 1 (S1): Mandatory labeling of GM-contains.

The first scenario investigates the impact of the new regulation on mandatory labeling of imported GM soybeans and GM corn that came into effect in January 2003. We assume that information on any GM-contains food product can be recorded and passed along the food marketing chain. Under such a traceability system, we could distinguish GM-contains from conventional foods.

The traceable mandatory labeling policy is simulated as adding a service charge required for GM-contained food production. According to a study by Vandeberg et al (2000), the IP identification cost for corn and soybean in the U.S. is about 3~9% of total production cost. Therefore, by taking the mean, we assume that the service charge would increase production cost by 6%. It means that in our simulation whoever uses GM-soybean or GM-corn in processing, the costs of its intermediate inputs would increase by 6%.

Scenario 2 (S2): Mandatory labeling with consumers' rejection toward GM products.

Beside the traceable mandatory labeling policy, we further consider consumers preferences toward GM products. After the traceable mandatory labeling policy is practiced, consumers are able to differentiate the GM products from conventional food. We therefore assume that consumers would become sensitive in the use GM technology in food production. According to the survey notified by the Department of Health in September 2002, about 70% of Taiwan's consumers are aware of the existence of GM food. Among these 70% consumers, only 22% of them have bad impressions on GM food. Therefore, we assume that 15.4% (70%*22%=15.4%) of consumers are reluctant to consume GM products.

Scenario 3 (S3): Import ban on GM soybean and GM corn.

In this extreme case, we assume that Taiwan bans the import of GM soybean and GM corn. Technically, this is modeled as the import volumes of those GM crops drop to zero. Also, in this case there is no need to impose any labeling cost or extra charge to trace them. However, the domestic price of soybean and corn would be increased. This import-ban scenario would reflect the most extreme application of the precautionary principle within the framework of the Biosafety Protocol.

4. Empirical results

The results of macro impacts are shown in Table 2. The adoption of traceable mandatory labeling of GM soybean and GM corn will lower the real GDP by -0.013%, a very moderate drop. Overall price index would increase 0.014%. This is mainly due to the increased costs of intermediate inputs when labeling policy is put into practice. If we consider consumer preference change after the labeling policy is in effect, it would not have any impact on macro economic variables. It means that consumers' attitude change could not affect the macro economy. However, it could increase the utility level by 0.0243% on an individual basis. Last, if Taiwan government implements the GM crops import ban, there would be a higher negative shock on real GDP (-0.29%). The overall price would increase 0.48%.

Table 2. Macro economic impacts under different scenarios

unit: %

Macro Impact	Scenario 1	Scenario 2	Scenario 3
Nominal GDP	0.0006	-0.0026	0.1867
Real GDP	-0.0132	-0.0153	-0.2909
Price index	0.0138	0.0127	0.4776
CPI	0.0255	0.0209	0.5479
Export	-0.0235	-0.0211	-0.5123
Import	0.0015	0.0097	0.0572
Terms of Trade	-0.0121	-0.0127	0.1419
Utility per person	0.0000	0.0243	0.0000

Source: model simulations.

The effects on outputs produced by different sectors are shown in Table 3 for the first two scenarios. Comparing the results of S1 and S2, there are significant differences in bother GM and non-GM product sectors. For example, when traceable mandatory labeling policy is implemented, there is very little change in the output of GM processing foods. However, adding consumers' attitude change would decrease the output of GM processing food by 1.6 billion NT dollars. It also stimulates an increase in the output of non-GM processing food because consumers would now turn to consume more non-GM food.

Table 4 shows the impacts on prices, employment and import of different sectors of the first two scenarios. Again, we can see that if we consider consumers' attitude change, there would be more significant impact on sectoral prices and labor employment because the substitute effects between GM-variety and non-GM variety.

Table 3. Impacts on output by sectors

Unit: million NT$

	Original Output	Scenario 1		Scenario 2	
		Value change	% change	Value change	% change
Paddy Rice	44,390	-40	-0.09	-107	-0.24
GM-soybean	27	-3	-12.12	-1	-4.86
Non-GM soybean	37	1	1.67	1	1.49
GM-corn	14	-2	-12.39	-1	-4.84
Non-GM corn	3,588	10	0.29	1	0.02
Other crops	6,614	-3	-0.04	-25	-0.38
Special & horticultural crops	149,305	-30	-0.02	-724	-0.49
GM-livestock	100,877	-293	-0.29	-1,268	-1.26
Non-GM livestock	216,147	-151	-0.07	737	0.34
Agricultural services	49,296	-35	-0.07	-141	-0.29
Forestry	1,110	0	-0.01	0	-0.02
Fish	110,026	-33	-0.03	-26	-0.02
Energy & mineral products	95,779	-19	-0.02	-7	-0.01
GM-oil and fats	17,715	-285	-1.61	-379	-2.14
Non-GM oil and fats	21,374	56	0.26	94	0.44
GM-animal feeds	21,295	-258	-1.21	-273	-1.28
Non-GM animal feeds	45,629	141	0.31	142	0.31
GM-processing foods	119,700	-120	-0.10	-1,595	-1.33
Non-GM processing foods	183,132	-147	-0.08	919	0.50
Beverages and tobacco	141,219	-14	-0.01	44	0.03
Leather products	896,109	-269	-0.03	-143	-0.02
Lumber and by-products	477,457	-95	-0.02	-27	-0.01
Chemical industry	1,754,504	-351	-0.02	-261	-0.01
Other industry products	5,490,840	-549	-0.01	-533	-0.01
Transportation	2,969,566	-594	-0.02	-1,235	-0.04
Services	9,252,678	-925	-0.01	722	0.01
Total	22,166,208	-4,007		-4,090	

Source：model simulations

Table 4. Impacts of economic indicator of different sectors (S1 and S2)

Unit : %

	Price		Employment		Import	
	S1	S2	S1	S2	S1	S2
Paddy Rice	-0.028	-0.195	-0.116	-0.323	-0.065	-0.253
GM-soybean	10.796	10.872	-16.510	-6.624	-3.257	-3.023
Non-GM soybean	0.139	0.100	2.317	2.059	2.250	2.259
GM-corn	10.388	10.504	-16.399	-6.403	-4.302	-4.054
Non-GM corn	0.097	-0.093	0.407	0.028	1.046	1.063
Other crops	-0.020	-0.230	-0.061	-0.523	-0.323	-0.437
Special & horticultural crops	0.014	-0.160	-0.022	-0.597	-0.023	-0.438
GM-livestock	0.608	-0.254	-0.703	-3.045	0.278	-0.465
Non-GM livestock	0.230	0.533	-0.160	0.825	0.121	0.419
Agricultural services	-0.072	-0.361	-0.136	-0.552	0.000	0.000
Forestry	-0.045	-0.106	-0.045	-0.080	-0.021	-0.028
Fish	0.015	0.021	-0.072	-0.050	0.003	0.022
Energy & mineral products	0.005	0.010	-0.029	-0.011	-0.013	-0.007
GM-oil and fats	2.252	1.786	-4.492	-5.955	2.483	1.127
Non-GM oil and fats	0.197	0.324	0.720	1.217	0.580	0.998
GM-animal feeds	0.821	0.778	-2.504	-2.660	-0.898	-1.029
Non-GM animal feeds	0.733	0.711	0.643	0.645	0.572	0.584
GM-processing foods	0.137	-0.135	-0.142	-1.926	0.172	-1.766
Non-GM processing foods	0.114	0.163	-0.116	0.725	0.146	0.898
Beverages and tobacco	0.019	0.034	-0.012	0.073	0.037	0.103
Leather products	0.004	0.006	-0.042	-0.024	0.000	0.033
Lumber and by-products	0.008	0.010	-0.025	-0.008	-0.001	0.020
Chemical industry	0.003	0.003	-0.032	-0.027	-0.006	0.000
Other industry products	0.003	0.004	-0.027	-0.018	-0.006	0.005
Transportation	0.010	-0.007	-0.025	-0.062	0.009	0.005
Services	0.013	0.024	-0.012	0.013	0.021	0.063

Source：model simulations

In the third scenario when Taiwan is engaged a ban on GM soybean and GM corn imports. Since Taiwan did not grow any GM crop, there would be no GM-contained product any more. Table 4 shows the output effects and price effects for this import ban policy. The output impacts are almost all negative across sectors, especially for livestock and the related processing sectors like oil and fat, animal feed. The total value of production would suffer a loss of 9.1 billion NT dollars. Prices for oil and fats and animal feeds would increase by 18.17% and 15.07%, respectively.

Livestock price will also increase 4%. Therefore, imposing import ban will force consumers to suffer from higher food prices. It would also force domestic soybean and corn production to increase at the expense of other agricultural production. It could also worsen the overall resource allocation efficiency.

Table 5. The Impact of import ban of GM soybean and GM corn (S3)

Unit : million NT$

	Original Output	Output		Price
		Value change	% Change	% Change
Paddy Rice	44,390	-1,010	-2.28	-0.76
Soybean	64	34	52.55	4.37
Corn	3,602	258	7.16	2.34
Other crops	6,614	-64	-0.97	-0.47
Special & horticultural crops	149,305	-632	-0.42	0.26
Livestock	317,025	-11,391	-3.59	4.15
Agricultural services	49,296	-773	-1.57	-1.62
Forestry	1,110	-2	-0.22	-0.98
Fish	110,026	-1,075	-0.98	0.43
Energy & mineral products	95,779	-393	-0.41	0.10
Oil and fats	39,089	-6,885	-17.61	18.17
Animal feeds	66,924	-9,713	-14.51	15.07
Processing foods	302,832	-3,673	-1.21	1.77
Beverages and tobacco	141,219	-181	-0.13	0.42
Leather products	896,109	-5,292	-0.59	0.09
Lumber and by-products	477,457	-1,763	-0.37	0.17
Chemical industry	1,754,504	-6,643	-0.38	0.06
Other industry products	5,490,840	-17,466	-0.32	0.06
Transportation	2,969,566	-10,747	-0.36	0.20
Services	9,252,678	-13,888	-0.15	0.28
Total	22,166,208	-91,295		

Source：model simulations

5. Concluding remarks

This paper investigates the impact of importing GM crops and related policy changes on Taiwan's economy and food sector. Under a general equilibrium context, we extend the existing model by distinguishing between GM and non-GM varieties as production inputs and as final consumption goods. We also endogenize consumers and producers choices in choosing between GM-contained and non-GM products so that consumers' concerns on food safety can be reflected into the policy simulations. The substitution of GM and non-GM foods is modeled by a CES function on the demand side, which then results in a ripple effect on domestic output on the supply side.

Our simulation results show that the traceable mandatory labeling of GM soybean and GM corn could only cause a slight decrease in domestic output. The real GDP would also be slightly decreased. However, when consumers are able to choose and reveal their reluctant to accept GM food under the mandatory labeling system, it would further induce the processors to decrease GM food production and transfer resources to produce non-GM foods. As a result, more significant changes in production and resource reallocations can be observed. Our result implies that although the social cost of a verifiable labeling system might not be too expensive to be a concern, the consumers' preference change might call for some serious structural realignment in Taiwan's agriculture and food processing industry. Policy makers should pay more attention to consumers' awareness and investigate the impact of how mandatory labeling policy would affect their consumption patterns.

If Taiwan imposes an import ban on GM crops, it would reduce real GDP and output of processing sectors and raise their prices in a substantial manner. This implies that the import ban would be a costly policy change for both producers and consumers in Taiwan.

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