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The brave new world: imperfect information, segregation costs, and genetically modified organisms

Schöne neue Welt: Unvollkommene Information, Kosten der Markttrennung und gentechnisch veränderte Organismen

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Abstract

The introduction of genetically modified (GM) crops in the mid 1990s appeared to be the latest in a string of technological innovations in agriculture. However, consumer resistance, particularly in Europe has limited the sector's enthusiasm. One response to the limited enthusiasm has been the emergence of segregated markets for GM and non-GM products. These separated markets reduce economic welfare because they require additional costs in the marketing system. Offsetting these segregation costs, however, the introduction of GM technologies offers increased economic welfare through reduced commodity prices for consumers who are indifferent to the presence of GM traits and increased profits to producers who adopt GM technologies. This study develops the combinations of segregation costs and increased supplies that leave societal surplus unchanged. Any GM technology that yields a larger increase in supply for any segregation cost depicted in this relationship meets the compensation principle and, thus, improves societal welfare. In this case, market based adoption of these technologies improve economic surplus. On the other hand, technologies that yields less increase in supply for any segregation cost reduces societal welfare. Under this scenario, market based adoption will not be welfare improving and, hence, government regulation may be required.

Key words

genetically modified (GM) crops; compensation principle; segregation costs; Pareto principle; immiserizing growth

Zusammenfassung

Dieser Beitrag überprüft die Wohlstandseffekte, die durch die Einführung von Pflanzen mit gentechnisch modifizierten Organismen (GVO-Pflanzen) sowohl für die Erzeuger von GVO- und Nicht-GVO-Pflanzen, als auch für die Verbraucher von GVO-und Nicht-GVO-Pflanzen entstehen. Es wird ein partielles Gleichgewichtsmodell der Märkte für GVO- und Nicht-GVO-Pflanzen formuliert, das Kosten der Markttrennung einbezieht, wie auch die Angebotsverschiebung, die durch die Einführung der GVO-Pflanzen verursacht wird. Anschließend wird das Modell verwendet, um die Kombinationen von Kosten der Markttrennung und von Angebotsverschiebungen zu bestimmen, die entweder eine Verbesserung oder eine Verschlechterung der gesellschaftlichen Wohlfahrt mit sich bringen. In den Fällen, in denen durch die Einführung der GVO-Pflanzen der Wohlstand steigen würde, kann eine staatliche Aktivität notwendig werden, um die potenziellen Verlierer durch die Einführung der GVO-Pflanzen zu kompensieren.

Schlüsselwörter

gentechnisch veränderte Lebensmittel; Kompensationsprinzip; Pareto-Kriterium; Kosten der Markttrennung; segmentierte Märkte

1. Introduction

Genetic modification of crops in the 1990s appeared initially to be the cutting edge in the ongoing quest for increased efficiency of agricultural technologies. However, unlike previous technological innovations such as hybrid corn, many consumers are concerned about the long-term health risks associated with the consumption of genetically modified (GM) crops. These concerns are most apparent in the European Union where regulatory authorities have prohibited the importation of crops such as hybrid (*B*t) corn (SCHMITZ et al., 2004). Following the AKERLOF (1970) seminal paper 'Market for Lemons', GRAY et al. (2004) demonstrate how the quality of food creates an information externality associated with the release of GM crops.

In this paper, we examine the welfare implications of introducing GM crops for GM and non-GM producers as well as for GM and non-GM consumers. We formulate a partial equilibrium model of the market for GM and non-GM crops that incorporates in it segregation costs and supply shifts caused by the introduction of GM crops. Using this partial equilibrium model, we derive the combinations of segregation costs and supply shifts that will leave societal welfare unchanged. For any fixed supply shift, segregation costs in excess of this equilibrium relationship results in a net decrease in social welfare while segregation costs lower than the equilibrium level results in an increase in welfare. Given these results we show that the adoption of GM technologies based on market incentives may actually reduce societal welfare. This adoption can be seen as an immiserizing technical change.

2. Basic segregation model

The introduction of GM commodities in the United States in the late 1990s spawned several changes within US agriculture. As a result of these changes, users of US corn, such as Frito Lay and Taco Bell, now utilize only GM-free corn. These changes also affected the exportation of US commercial GM agricultural innovations to Europe. The US livestock industry, however, is unconcerned with the content of GM corn used for livestock feed, because few US livestock operations cater to the non-GM meat market. This emergence of a demand for GM-free products has generated a

market in which farmers, elevator operators, and processors incur segregation costs when pursuing a market premium for GM-free corn. In this section of our paper, we present an economic model of this market segregation. First, we review the implications of imperfect information within the segregated marketing channel. Second, we present an economic model of the effect of these segregation costs on the market equilibrium for corn.

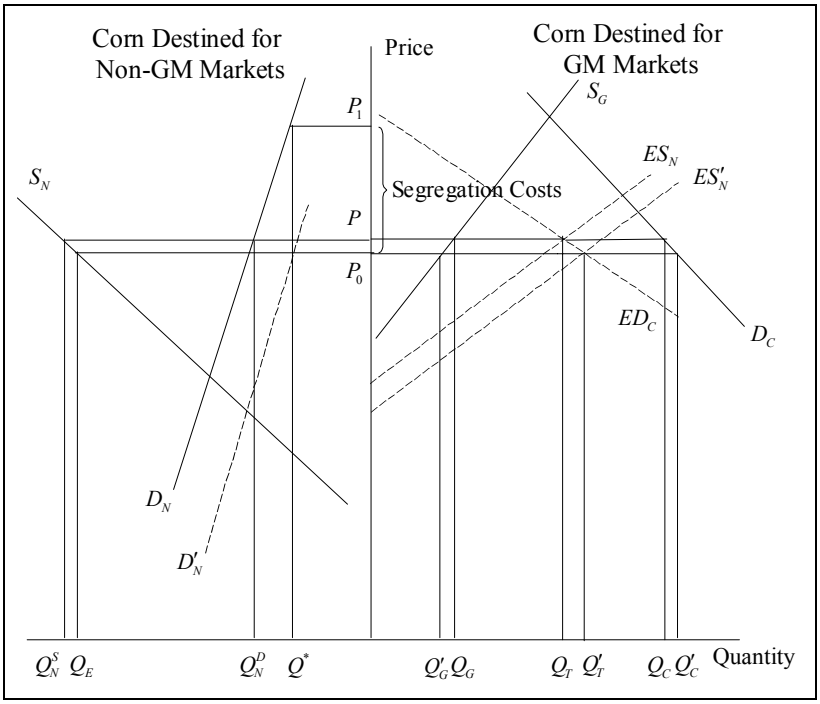
Imperfect information enters the market for GM commodities. First, the long-run health consequences of consuming GM commodities are as yet unknown. While uncertainty implies imperfect knowledge, however, it does not constitute a market imperfection (PHILIPS, 1988). Imperfect information within the economic literature refers to the scenario in which uncertainty exits, but the information observed by different agents differs. It is this difference in information known by each agent coupled with uncertainty that give rise to strategic behavior that distorts efficient markets. Thus, imperfect information about the long-run health consequences of consuming GM commodities implies uncertainty, but unless consumers or producers have inside information about these consequences, the market equilibrium does not suffer from imperfect information. Thus, market equilibrium is not distorted by strategic behavior. However, uncertainty about the long-run health consequences of consuming altered commodities supports a reduction in the demand for GM commodities (OI, 1973).

The second possible effect of imperfect information for GM commodities is the impact imperfect information has on the marketing channel. SCHMITZ et al. (2004) emphasize the role of segregation costs within the marketing channel. These segregation costs drive a wedge between the price received by producers and the price paid by consumers and results in a loss of economic surplus, which is a topic we develop in this paper. While segregation costs represent the real costs of testing and separating non-GM grain from GM grain, the costs are also affected by imperfect information and by strategic behavior. Given that production practices reducing the chance of a GM-contamination event are costly to monitor, and given that premiums resulting from this segregation of non-GM grain give rise to strategic behavior, the market channel for GM-free crops will cause increased testing expenses.

SCHMITZ et al. (2004) examine the welfare implications of the introduction of GM soybeans into the marketplace by focusing on the advent of the costs of segregation for non-GM crops and by pinpointing the supply shifts resulting from the costs savings afforded by this new technology. Their study took additional segregation costs and supply shifts as fixed and determined the net welfare effect of the GM-corn contamination event. This paper extends the SCHMITZ et al. basic formulation by solving for the combination of segregation costs and supply shifts that leave societal welfare unchanged. Building on the insights of SCHMITZ et al., supply shifts higher than what would be required to offset the incremental segregation costs improve societal welfare while supply shifts lower than that level result in a net loss of societal welfare surplus.

We present the general form of a segregation model in figure 1, in which there is a net excess supply of non-GM corn ES_N defined as the supply of non-GM corn S_N less the demand for non-GM corn D_N. This graphical representation is consistent with the state of the US corn market prior to the introduction of GM corn. While RUNGE and RYAN (2003) indicate that 40% of all US corn planted in 2003 was GM corn, LIN (2002) finds that only 1% to 2% of US corn demand is sensitive to GM content. Thus, at current market prices, the supply of non-GM corn exceeds the demand for non-GM corn. Segregation costs shift the excess supply curve of non-GM corn outwardly from ES_N to ES'_N, which results from the inward shift in demand from D_N to D'_N due to segregation costs. The excess demand of GM corn ED_C is defined as the demand of potential GM corn D_C less the supply of potential GM corn S_G. Before segregation costs are introduced, Q_N^D bushels of corn are consumed for non-GM uses and Q_N^S bushels of corn are produced. Likewise, before segregation costs are imposed, Q_G bushels of GM corn are produced and Q_C bushels of corn are consumed by uses that are not sensitive to GM content. After the introduction of segregation costs Q^* bushels of non-GM corn are consumed and Q_E bushels of non-GM corn are produced. Similarly, the quantity of GM corn produced falls to Q'_G bushels while the consumption of potential GM corn increases to Q'_C. Given the excess

Figure 1. Effect of segregation costs on the market price for GM and non-GM corn



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supply of non-GM corn, it is impossible for a price premium to emerge in excess of segregation costs $P_1 - P_0$. As a result, the price of corn received by farmers falls from P to P_0.

The market equilibrium, given segregation costs τ and supply shifts due to GM technologies ψ, can be written as

$$D^T(p,\tau) = D^N(p+\tau) + D^G(p) = S^N(p) + (1+\psi)S^G(p) = S^T(p) \tag{1}$$

where p is the prevailing market price; $D^T(p,\tau)$ is the total demand for the crop; $D^N(p+\tau)$ is the non-GM demand; $D^G(p)$ is the undifferentiated or GM demand; $S^N(p)$ is the supply of non-GM output; ψ is the shift in supply due to the adoption of GM crops; $S^G(p)$ is the supply of GM crop; and $S^T(p)$ is the total supply of both non-GM and GM crops. Based on the market equilibrium in equation 1, we show that the introduction of GM crops reallocates producer and consumer surplus for both GM and non-GM producers and consumers. In general, non-GM producers and consumers lose with the introduction of GM varieties. Non-GM consumers lose because of the introduction of segregation costs. Non-GM producers lose because of the reduction in non-GM demand that shifts the aggregate demand curve to the left (SCHMITZ et al., 2004) and because of increased competition from GM producers whose supply curves increase as they adopt new GM technologies. The net gain for GM producers can be positive or negative depending on the relative supply and demand elasticities and on the nature of the supply shift associated with the release of GM crops. However, GM-crop consumers gain unambiguously from the introduction of GM technology.[1] The net gain or net loss to society based on these changes is an open question that depends on the relative size of the segregation costs and of the supply shift.

3. Welfare changes from the introduction of genetically modified crops

In this application, we define the societal welfare from the corn market as

$$\int_{p^*+\tau}^{\overline{p}_N} D^N(p)\,dp + \int_{p^*}^{\overline{p}_G} D^G(p)\,dp + \int_{\underline{p}_N}^{p^*} S^N(p)\,dp + (1+\psi)\int_{\underline{p}_G}^{p^*} S^G(p)\,dp = W(\tau,\psi) \tag{2}$$

where $\overline{p}_N$ is the choke price for non-GM consumers; $\overline{p}_G$ is the choke price for GM consumers; p^* is the equilibrium price that is defined as the price that equates the total quantity demanded and the total quantity supplied in equation 1 for a given combination of segregation costs and supply shifts; $\underline{p}_N$ is the choke price for non-GM producers; $\underline{p}_G$ is the choke price for GM producers; and $W(\tau,\psi)$ is the welfare from the production and consumption of corn as a function of the segregation costs and of the supply shift. Because of segregation costs, we have defined these integrals using price instead of quantity. Applying the Leibniz rule

$$dp^*\left[-\int_{p^*+\tau}^{\overline{p}_N} D^N(p)\,dp - \int_{p^*}^{\overline{p}_G} D^G(p)\,dp + \int_{\underline{p}_N}^{p^*} S^N(p)\,dp + \int_{\underline{p}_G}^{p^*} S^G(p)\,dp\right] - d\tau\int_{p^*+\tau}^{\overline{p}_N} D^N(p)\,dp + d\psi\int_{\underline{p}_G}^{p^*} S^G(p)\,dp = dW(\tau,\psi) \tag{3}$$

Separating the result of equation 3, the first component of a change in welfare results directly from a change in the equilibrium price. As the equilibrium price increases, consumer surplus for both GM consumers and non-GM consumers declines as the producer surplus for both GM producers and non-GM producers increases. However, the increase in segregation costs implies a reduction in the non-GM consumer surplus, while the supply shift implies an increase in producer surplus that accrues to GM producers.

The change in societal welfare resulting from the need to segregate GM corn from non-GM corn can be derived from equation 3 as

$$\frac{dp^*}{d\tau}\left[-\int_{p^*+\tau}^{\overline{p}_N} D^N(p)\,dp - \int_{p^*}^{\overline{p}_G} D^G(p)\,dp + \int_{\underline{p}_N}^{p^*} S^N(p)\,dp + \int_{\underline{p}_G}^{p^*} S^G(p)\,dp\right] - \int_{p^*+\tau}^{\overline{p}_N} D^N(p)\,dp + \frac{d\psi}{d\tau}\int_{\underline{p}_G}^{p^*} S^G(p)\,dp = \frac{dW(\tau,\psi)}{d\tau} \tag{4}$$

Similarly, the change in societal welfare resulting from a shift in the GM supply curve can be derived as

$$\frac{dp^*}{d\psi}\left[-\int_{p^*+\tau}^{\overline{p}_N} D^N(p)\,dp - \int_{p^*}^{\overline{p}_G} D^G(p)\,dp + \int_{\underline{p}_N}^{p^*} S^N(p)\,dp + \int_{\underline{p}_G}^{p^*} S^G(p)\,dp\right] - \frac{d\tau}{d\psi}\int_{p^*+\tau}^{\overline{p}_N} D^N(p)\,dp + \int_{\underline{p}_G}^{p^*} S^G(p)\,dp = \frac{dW(\tau,\psi)}{d\psi} \tag{5}$$

[1] The finding that the increase in demand will lead to an unambiguous increase in consumer welfare must be viewed with caution. DIXIT and NORMAN (1978) and ALSTON et al. (1999) find that changes in demand resulting from advertising do not always increase social welfare. In the case of DIXIT and NORMAN, deviation is linked to market power; the result obtained by ALSTON et al. appears to be the result of adding-up restrictions on a demand system.

In order to proceed further, we first assume that a market equilibrium exists so that

$$D^N\left(p^*+\tau\right)+D^G\left(p^*\right)-S^N\left(p^*\right) -\left(1+\psi\right)S^G\left(p^*\right)=0 \tag{6}$$

Taking a first-order Taylor series expansion around the point of equilibrium

$$q^D=\left[a_N^D+b_N^D\left(p^*+\tau\right)\right]+\left[a_G^D+b_G^D p^*\right]= \left[a_N^S+b_N^S p^*\right]+\left(1+\psi\right)\left[a_G^S+b_G^S p^*\right]=q^S, \tag{7}$$

where the first order specification results in a parallel shift in both the supply relationship $\left(1+\psi\right)$ and in each demand equation. Equilibrium ($q^D=q^S$) then implies that

$$\begin{aligned}&\left[a_N^D+a_G^D-a_N^S-\left(1+\psi\right)a_G^S\right]+\\ &\left[b_N^D+b_G^D-b_N^S-\left(1+\psi\right)b_G^S\right]p^*+b_N^D\tau=0\\ &\Rightarrow p^*=-\frac{\left[a_N^D+a_G^D-a_N^S-\left(1+\psi\right)a_G^S\right]+b_N^D\tau}{\left[b_N^D+b_G^D-b_N^S-\left(1+\psi\right)b_G^S\right]}.\end{aligned} \tag{8}$$

This result implies that

$$\frac{dp^*}{d\tau}=-\frac{b_N^D}{\left[b_N^D+b_G^D-b_N^S-\left(1+\psi\right)b_G^S\right]}<0 \tag{9}$$

Substituting this result into equation 4 and setting $d\psi/d\tau=0$ yields the result that the imposition of segregation costs on the marketing channel for GM crops without a shift in supply reduces societal welfare. Unfortunately, the direction of the change in price with respect to the increase in the supply-shift parameter ψ is ambiguous because

$$\begin{aligned}\frac{dp^*}{d\psi}&=\frac{a_G^S}{\left[b_N^D+b_G^D-b_N^S-\left(1+\psi\right)b_G^S\right]}\\ &-\frac{\left[a_N^D+a_G^D-a_N^S-\left(1+\psi\right)a_G^S\right]+b_N^D\tau}{\left[b_N^D+b_G^D-b_N^S-\left(1+\psi\right)b_G^S\right]^2}b_G^S\end{aligned} \tag{10}$$

could be positive or negative. Thus, the effect of the shift in supply is dependent on the supply elasticity and on the demand elasticity.

4. Self-enforcing innovation: when technological change meets the compensation principle

The foregoing discussion follows the SCHMITZ et al. (2004) approach of examining the impact of adding segregation costs independent from the potential shift in supply. However, it is possible that some combination of segregation cost and supply shift exists such that it leaves societal surplus unchanged. Equation 3 can be solved for those combinations of τ and ψ so that $dW\left(\tau,\psi\right)=0$. These solutions of social welfare separate the set of all possible segregation costs and supply shifts into those change that increase social welfare (i.e., those innovations where the compensation principle is met) and those solutions that decrease social welfare (i.e., those innovations that are immiserizing).

To derive the combinations of segregation costs and supply shifts that leave societal surplus unchanged, we begin with the 2003/04 US corn baseline obtained from the US Department of Agriculture baseline quantity supplied of 10.2 billion bushel at a price of US$ 2.35 per bushel. We assume that 2% of the corn consumed in the United States is stipulated GM-free (LIN, 2002) and that 40% of the corn planted is GM corn (RUNGE and RYAN, 2003). Next, we assume two linear derived-demand curves that have a derived-demand elasticity for US non-GM corn of –0.2 and an aggregate derived demand elasticity for US corn of –0.3. Finally, we assume that the supply of both GM corn and non-GM corn equals 0.5 and that the shutdown price for both supply curves is US$ 1.25 per bushel. In table 1 (column 1), we reproduce the baseline production and consumption of GM or non-GM corn.

We now introduce a segregation cost of US$ 0.05 per bushel and solve numerically for the increase in supply that leaves overall surplus unchanged. Thus, if 40% of the original supply is GM corn, a 0.3% increase in the supply of GM corn will leave the aggregate surplus unchanged. This combination of segregation costs and supply shifts results in a 0.14% price decline in the market price for US non-GM corn from US$ 2.35 per bushel to US$ 2.347 per bushel. Combining this change in market price with the corresponding costs of segregation, non-GM consumers will pay US$ 2.397 per bushel following the introduction of segregation costs. Given this increase in the price of GM-free corn, the demand for non-GM corn will fall by 0.4% from 0.2 billion bushels to 0.199 billion bushels. Similarly, as the price paid for GM or undifferentiated corn declines, the demand for GM corn will increase from 10.000 billion bushels to 10.004 billion bushels. Thus, the demand for all US corn will increase only slightly from 10.200 billion bushels to 10.203 billion bushels.

Since the price of GM corn received by farmers net of segregation costs declines, the quantity of non-GM corn on the supply side of the market will decline by 0.004 billion bushels. However, this decline is more than offset by the 0.008 billion bushel increase in the supply of GM corn. The increased supply of GM corn is largely the result of the 0.3% supply shift introduced in the marketplace from the introduction of innovative GM technology at the farm level. This outward shift, however, is offset partially by the reduction in the price of corn.

By construction, we hold societal welfare in table 1 constant at US$ 49.989 billion. However, the introduction of GM corn affects the allocation of economic surplus across all producers and consumers of GM and non-GM corn. Numerically, the surplus of non-GM consumers falls from US$ 1.175 billion to US$ 1.166 billion, which is a decline of 0.8%. Similarly, non-GM producers will experience a 0.3% loss in producer surplus, and GM producers will experience a small net loss of producer surplus. The gain in welfare accrues to those consumers who are not concerned about the difference between GM and non-GM corn. Thus, the GM corn consumer surplus will increase from US$ 38.907 billion to US$ 38.939 billion.

Table 1. Market solutions with societal welfare constant

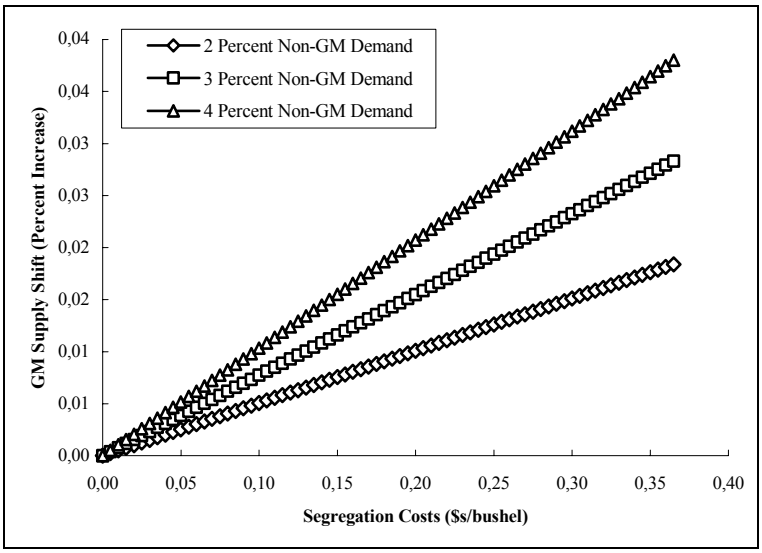
	Segregation costs ($/bushel)					
	0.00	0.05	0.10	0.15	0.20	0.25
Percent increase in supply	0.000	0.003	0.005	0.008	0.010	0.013
Equilibrium price	2.350	2.347	2.344	2.340	2.337	2.334
Non-GM corn demanded	0.200	0.199	0.198	0.198	0.197	0.196
GM corn demanded	10.000	10.004	10.008	10.012	10.016	10.021
total demand	10.200	10.203	10.207	10.210	10.213	10.217
Non-GM corn supplied	6.120	6.116	6.112	6.107	6.103	6.099
GM corn supplied	4.080	4.088	4.095	4.102	4.110	4.117
total supply	10.200	10.203	10.207	10.210	10.213	10.217
Non-GM consumer surplus	1.175	1.166	1.156	1.147	1.138	1.129
GM consumer surplus	38.907	38.939	38.971	39.003	39.035	39.067
total consumer surplus	40.082	40.105	40.128	40.150	40.173	40.196
Non-GM producer surplus	5.944	5.925	5.905	5.886	5.866	5.847
GM producer surplus	3.963	3.960	3.957	3.953	3.950	3.947
total producer surplus	9.907	9.884	9.862	9.839	9.816	9.793
societal surplus	49.989	49.989	49.989	49.989	49.989	49.989

Source: authors' computations

From the above, the change in economic rents due to the introduction of GM technologies with associated segregation costs and increased supply will be zero. If the GM consumers who gain from the introduction of the technology pay the losses of the non-GM producers, non-GM consumers, and GM producers who are the losers, the gainers will be indifferent to the introduction of the GM technology and to the use of traditional varieties. Holding the segregation costs constant at US$ 0.05 per bushel, however, a supply shift for GM corn of more than 0.3% will yield a net increase in societal welfare. Thus, if the introduction of a GM technology yields a supply increase of more than 0.3%, the gainers who are the GM consumers could compensate the losses of the losers who are the non-GM producers, non-GM consumers, and GM producers such that the GM consumers will remain better off.

In figure 2, we extend the numerical results of table 1 by depicting the combinations of segregation costs and supply shifts that leave societal welfare unchanged. The lowest frontier is associated with the baseline scenario of table 1 in that 2% of the original supply is sensitive to the introduction of GM corn. Two other scenarios are presented in figure 2 in which the highest locus of points depicts the solution where the non-GM demand for corn is 4% of the supply of original corn while the middle locus of points represents solutions where the GM demand for corn is 2% of the original supply of corn. Along the locus of point for the baseline 2% solutions, the gain to individuals from the introduction of GM technologies is exactly the same as the loss incurred by the losers. For combinations of segregation costs and supply shifts above this relationship, the introduction of GM technologies results in a net increase in societal welfare. Thus, the introduction of GM technologies for combinations of segregation costs and supply shifts above this relationship meet the compensation principle.

Figure 2. Combinations of supply shift and segregation costs that leave aggregate surplus unchanged



Source: authors' compilation

Specifically, a low separation cost relative to the supply shift (than depicted in the linear relationship between segregation costs and shift in supply in figure 2) implies increased societal welfare from the market adoption of GM technology. Alternatively, a large segregation cost relative to the supply shift will imply a loss in societal welfare with the introduction of GM technologies, even if the GM consumers gain from technological adoption. Under the latter scenario, society is better off without the introduction of GM crops.

The boundary between the combination of segregation costs and supply shifts that meet the compensation principle is fragile to several factors in the segregation model of equation 1. Most notably, the frontier is dependent on the relative share of non-GM demand. The two other relationships give the combination of segregation costs and supply shifts that leave societal surplus unchanged as the share of the non-GM demand for corn increases relative to total corn demand. As the relative size of the non-GM corn demand increases, the shift in supply required to offset the segregation costs also will increase. Hence as the share of non-GM demand increases, the potential role of government regulation via market operation will also increase.

5. Pareto, compensation, and immiserizing technological change

From the foregoing discussion in the presence of segregation costs and supply shifts, the adoption of GM technologies cannot be Pareto improving assuming compensation is not paid. Non-GM consumers, non-GM producers, and GM producers all lose while GM consumers gain with the release of GM varieties.

However, certain combinations of segregation costs and supply shifts will leave societal welfare unchanged. Technological change that yields a larger supply shift for given segregation costs will meet the compensation principle. This implies that market-based decisions to adopt such technolo-

gies improve societal welfare. Alternatively, technological changes that produce smaller shifts in supply for given segregation costs reduce societal welfare, hence government regulations to discourage GM adoption may be warranted.

The introduction of GM crops could separate both producers and consumers into two groups (GRAY et al., 2004). Some producers may find the adoption of GM technology will be advantageous, while another group may find that the benefits of GM technologies will not exceed their costs. Similarly, consumers may decide that the consumption of GM commodities will not decrease their expected utility, while other consumers may be more risk adverse and decide that GM commodities will decrease their expected utility (OI, 1073). Other economic agents, including processors and grain-elevator operators involved in the corn market, may serve as middlemen for a choice made by a producer. Each group of consumers and/or producers may optimize its preference independently, but each group will be affected by the decision of the remaining group. For example, consumers who choose not to consume GM commodities are exposed to higher commodity prices due to positive segregation costs because of the adoption decisions made by producers who choose to adopt GM technologies. Similarly, GM producers may be affected by reduced demand for corn that can result from the decision by some consumers to not consume GM commodities.

If producers have an incentive to adopt GM technology while the net welfare effect of adoption is negative, in this case it leads to immiserizing growth.[2] Thus, adoption of GM technologies may be in the best interest of some producers. As demonstrated in our welfare model in this paper, the welfare impact on non-GM consumers and producers may more than offset the welfare gain to the adopters. In this sense the innovation is an immiserizing technical change.

As demonstrated earlier, from a policy context it is unlikely that the introduction of GM technologies will ever meet the Pareto principle. Thus, the question facing policymakers is whether or not the introduction of these technologies *could* meet the compensation principle. If the introduction of GM technologies fail to meet the compensation principle, it is possible that producers will decide optimally to adopt the new technology even though such adoption represents an immiserizing technical change. However, it is conceivable that the introduction of GM technologies *could* meet the compensation principle, hence the introduction of GM technology could be welfare improving. The role of government is quite different under each scenario. If the technological change is immiserizing, government ban on GM technology would improve social welfare. On the other hand, the government should let the market determine whether GM technologies should be adopted if the technology meets the compensation principle.

6. Conclusions

The introduction of GM crops in the 1990s appears to be the latest innovation in the agricultural sector that would yield benefits to society through lower food prices. Emerging consumer concerns regarding the long-term health effects of GM crops has raised several issues about the economic benefits of such new technologies. One response to consumer concerns has been the establishment of segregated market channels for GM-free commodities. This approach represents a market-based response to biotechnology as opposed to the regulatory approach implicit in the moratoria on the importation or production of GM crops.

In this paper, we examined whether or not the introduction of GM crops meet the compensation principle. Combinations of segregation costs and supply shifts that do not meet the compensation principle result in net welfare losses to society. If the adoption of such technologies is left up to the marketplace, the resulting technological change will be immiserizing. This possibility suggests a role for government regulation rather than relying on market mechanism to dictate the release of GM varieties.

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[2] SCHUMPETER (1942) introduces the idea of immiserizing technical change in that technical change leaves overall economic well-being less profitable than it was before the innovation was applied.

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