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Consumption effects of genetic modification: what if consumers are right?☆

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Abstract

This paper develops a model of differentiated consumers to examine the consumption effects of genetic modification (GM) under alternative labelling regimes and segregation enforcement scenarios. Analytical results show that if consumers perceive GM products as being different than their traditional counterparts, GM affects consumer welfare and, thus, consumption decisions. When the existence of market imperfections in one or more stages of the supply chain prevents the transmission of cost savings associated with the new technology to consumers, GM results in welfare losses for consumers. The analysis shows that the relative welfare ranking of the 'no labelling' and 'mandatory labelling' regimes depends on: (i) the level of consumer aversion to GM products; (ii) the size of marketing and segregation costs under mandatory labelling; (iii) the share of the GM product in total production; and (iv) the extent to which GM products are incorrectly labelled as non-GM products.

JEL classification: D11; D82; L15; Q13; Q18

Keywords: Consumer welfare; Genetic modification; Labelling; Mislabelling; Segregation costs

1. Introduction

Consumer concern about genetic modification (GM) of food is one of the most notable features of agricultural biotechnology. Unlike farmers, who have seen agronomic benefits in the new technology and have quickly adopted transgenic plants such as Bt cotton and corn and herbicide-resistant soybeans and canola (Economic Research Service, 1999), consumers have expressed reservations about the foods produced from these crops. Consumer opposition to GM products started in Europe and has spread to other countries.

An Angus Reid poll in eight countries (France, Germany, UK, Australia, Canada, US, Japan and Brazil) found that among people aware of genetically modified foods, 68% on average indicate they would be "less likely" to purchase a food product if they knew it contained genetically modified ingredients. The proportion of respondents expressing aversion to GM products varied between 57% in the US and

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83% in Germany (The Economist, 2000). In an earlier poll in the UK (MORI poll), 77% of those surveyed favoured a ban on GM food. Consumer resistance to GM is founded on health, environmental, moral and philosophical concerns about the 'new' practice (Hobbs and Plunkett, 1999; Lindner, 2000).

In response to this consumer reaction, a number of food companies, such as Marks and Spencer, McDonalds, Sainsbury, and Tesco in the UK, Nestle in Switzerland, Carrefour in France, McCains in Canada, and Frito Lay in the US, have indicated that they are only accepting/selling non-GM products. Governments in the European Union (EU) and elsewhere have also responded by introducing mandatory labelling or by banning specific GM products (i.e. GM corn and canola in Austria, France, Greece, and Luxembourg) (Hobbs and Plunkett, 1999; Runge and Jackson, 2000). At the international level, the Biosafety Protocol signed by 130 countries in 2000 in Montreal required that shipments of living genetically modified products (such as seeds) are to be labelled as such.

While labelling of food products satisfies consumer demand for the right to make informed consumption decisions (Caswell and Mojduszka, 1996; Caswell, 1998), the introduction of segregation and labelling raises a number of issues that affect everyone in the food chain. One issue is the added costs that segregation and labelling introduce and the economic impact of these costs on consumers. A second issue is that segregation and labelling activities create incentives for the misrepresentation and mislabelling of GM products as traditional food. Although, there is a growing literature on the nature and origin of consumer attitudes towards GM products, most of the analysis on the economic consequences of these attitudes is rather heuristic in nature. An exception is the paper by Plunkett and Gaisford (2000) who examine the welfare effects of introducing GM products, but do not consider consumer heterogeneity or examine the possibility of mislabelling.

The objective of this paper is to develop a conceptual model that examines the consumption effects of GM under alternative labelling regimes and segregation enforcement scenarios. More specifically, the paper analyses the effect of GM products on the welfare and purchasing decisions of consumers under: (i) no labelling; (ii) mandatory labelling under full compliance; (iii) and mandatory labelling when misrepresentation of the type of the product (i.e. mislabelling) occurs.

In analysing the consumption effects of GM, this paper explicitly accounts for consumer heterogeneity. To capture the different attitudes towards GM, consumers are postulated to differ in the utility they derive from the consumption of GM products and therefore in their willingness-to-pay (WTP) for these products. Consumer heterogeneity is critical in understanding how demand for both GM and non-GM products exists when labelling occurs.

In this paper, 'genetically modified' products refers to transgenics-products in which some form of gene 'splicing' has occurred. The new technology is assumed to generate production cost savings while having no effect on product characteristics that are observable by consumers; the analysis thus applies to the producer-oriented first generation GM products that are credence in nature.

The title of the paper stems from the major result of the analysis, namely, that if consumers perceive GM products to be different from their non-GM counterparts, then there is a reasonable expectation that a percentage of consumers will correctly believe that the introduction of GM products lowers their utility and would prefer to see these products banned. The key factors that determine the magnitude of this welfare loss are the degree of aversion to GM products, the degree to which the cost savings at the farm level are not passed through to consumers, and the magnitude of the costs associated with segregating non-GM products from GM products. Although, this group would like to ban GM products, when faced with the introduction of GM products as a given, this group will prefer mandatory labelling to no labelling.

The paper is structured as follows. Section 2 presents the conceptual model. Sections 3–5 examine the effect of GM on consumer decisions and welfare under no labelling, mandatory labelling with full compliance, and mandatory labelling with mislabelling, respectively. Section 6 compares and contrasts the no labelling and the mandatory labelling regimes while Section 7 summarises and concludes the paper.

2. Consumer characteristics and behaviour

The rise of consumer concerns over GM products and the diversity of these concerns suggests that consumers differ in their WTP for GM versus non-GM food products. In the simplest case, consider a consumer that consumes one unit of either a traditional, a GM, or a substitute product. Assuming that the consumer spends a small fraction of total expenditure on the goods in question, her utility function can be written as:

$U_{\text{t}} = U - p_{\text{t}}$

if a unit of traditional product is consumed,

$U_{\text{gm}} = U - p_{\text{gm}} - \lambda c$

if a unit of GM product is consumed,

and

$U_{\text{s}} = U - p_{\text{s}}$

if a unit of a substitute product is consumed

where U_{t} is the utility associated with purchasing one unit of the traditional product, U_{gm} the utility associated with purchasing one unit of the GM version of the traditional product, and U_{s} the utility associated with purchasing one unit of a substitute product.[1] The price of the traditional product is p_{t}, the price of its GM counterpart is p_{gm}, and the price of the substitute product is p_{s}. The parameter U is a per unit base level of utility while the term λc gives the discount in utility from consuming GM product.[2] The parameter λ is a non-negative utility discount factor while the characteristic c differs according to consumer and captures the consumer's aversion towards GM products. To simplify the analysis, the characteristic c takes values between 0 and 1. Consumers with large values of c prefer the traditional product rather than the GM product, all else equal. The assumption that λc is greater than or equal to 0 is consistent with evidence showing that consumers are either indifferent or opposed to GM products (Hobbs and Plunkett, 1999).[3] The analysis initially assumes that consumers are uniformly distributed between the polar values of c. This assumption is then modified to allow a bunching or a concentration of consumers at the ends of the spectrum (i.e. 0 and 1).

Fig. 1 illustrates the situation where no GM product has been introduced. By assumption, the net utility associated with the traditional good is greater than that associated with the substitute good, i.e. $U - p_{\text{t}} > U - p_{\text{s}}$, for all consumers. In such a case, all consumers purchase the traditional good and total consumer welfare is given by the shaded area in Fig. 1. The effect of introducing GM products into the market is examined in the following sections.

3. Consumer behaviour when GM products are not labelled

Consider first the situation where a GM product is introduced, but no labelling of the product is carried out. Because the GM product and its traditional counterpart are marketed together, the price faced by the consumer, p_{nl}, is the same regardless of which product is purchased. The lack of information about the type of the product being sold means that consumers are uncertain as to the nature of the product they purchase. Since the presence or absence of the GM is not detectable with either search or experience, the GM can be referred to as a *credence* characteristic (Darby and Karni, 1973; Nelson, 1974). Assuming a

[1] One example of a product that could be supplied in both a traditional and a GM form is margarine made from canola. In this case, butter can be thought of as a substitute product. A second example could be corn chips (made from traditional or GM corn); the substitute product is potato chips. Other examples of traditional, GM, and substitute products include meat coming from animals fed with (traditional or GM) corn or soybean versus meat coming from animals that are barley fed. For simplicity and without loss of generality, it is assumed that the substitute product (butter, potato chips and meat coming from barley fed animals in the preceding examples) is free of GM ingredients. The implications of relaxing this assumption are discussed in footnote 6.

[2] U can also be interpreted as the maximum WTP for a unit of the traditional or the substitute product. In such a case, consumer maximum WTP for the GM product equals $U - \lambda c$. The difference between the WTP and the price of the (traditional, the GM, or the substitute) product then provides an estimate of the relevant consumer surplus.

[3] While our analysis applies to the producer-focused, first generation, GM products, the model can be extended, with some modification, to analyse the consequences from the introduction of consumer-oriented GM products. Specifically, if the new generation of GM products manages to possess attributes valued by consumers (e.g. nutraceuticals), the current aversion to GM products could become preference for GM products with desirable characteristics. In such a case, the parameter c in the model would capture heterogeneous consumer preferences and λc would represent utility enhancement (rather than utility discount) from the consumption of GM products (i.e. the relevant utility function would be written as $U_{\text{gm}} = U - p_{\text{gm}} + \lambda c$).

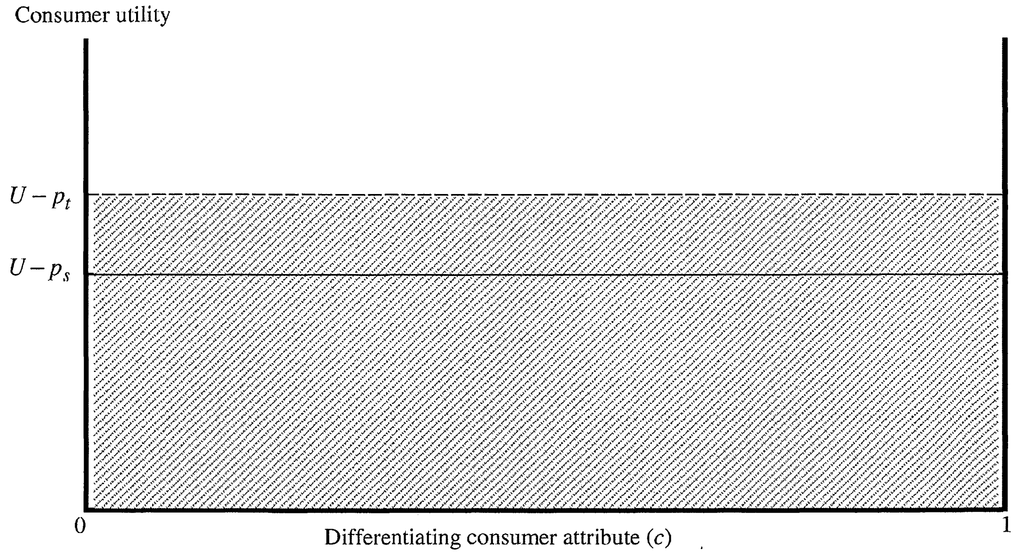

Fig. 1. Consumer decisions and welfare prior to the introduction of GM food.

probability of ψ that the non-labelled product purchased is GM, consumer utility is now[4]

$$U_{\rm nl} = U - p_{\rm nl} - \psi\lambda c$$

if a unit of non-labelled product is consumed,

and

$$U_{\rm s} = U - p_{\rm s}$$

if a unit of a substitute product is consumed

where $U_{\rm nl}$ is the expected per unit utility associated with purchasing the non-labelled product (i.e. $U_{\rm nl} = \psi U_{\rm gm} + (1-\psi)U_t$).

The consumption choice of the individual consumer is determined by the relationship between the utilities derived from the non-labelled product and the substitute. More specifically, the consumer with aversion to GM product given by:

$$c^*_{\rm nl} : U_{\rm nl} = U_{\rm s} \Rightarrow c^*_{\rm nl} = \frac{p_{\rm s} - p_{\rm nl}}{\psi\lambda}$$

is indifferent between consuming a unit of non-labelled product and a unit of the substitute—the utility associated with the consumption of these offerings is the same. Obviously, consumers with a lower aversion to GM products (i.e. consumers with $c \in [0, c^*_{\rm nl})$) will prefer the non-labelled product while consumers with higher aversion to GM products (i.e. consumers with $c \in (c^*_{\rm nl}, 1]$) will consume the substitute.[5]

Since consumers have been assumed to be uniformly distributed with respect to their aversion to GM products, the level of aversion corresponding to the indifferent consumer, $c^*_{\rm nl}$, also determines the share of the non-labelled product to total consumption, $s_{\rm nl}$. The consumption share of the substitute, $s_{\rm s}$, is given by $1 - c^*_{\rm nl}$. More specifically, $s_{\rm nl}$ and $s_{\rm s}$ can be written as:

$$s_{\rm nl} = \frac{p_{\rm s} - p_{\rm nl}}{\psi\lambda} \quad (= c^*_{\rm nl})$$

[4] The probability that the non-labelled product is GM can be seen as reflecting the share of the GM product in total production (i.e. the portion of margarine that is genetically modified in the example provided in footnote 1). The greater is the production share of the GM version of the product, the greater is the likelihood that the non-labelled product is GM.

[5] The focus of the analysis on individuals that were consumers of the product prior to its genetic modification guarantees the positive sign of $c^*_{\rm nl}$. More specifically, for consumers to prefer the product prior to its genetic modification it should hold that $U - p_{\rm t} > U - p_{\rm s}$ where $p_{\rm t}$ represents the price of the product before genetic engineering. Due to the cost savings associated with the new technology, the price of the non-labelled product $p_{\rm nl}$ will be less than, or equal to, $p_{\rm t}$.

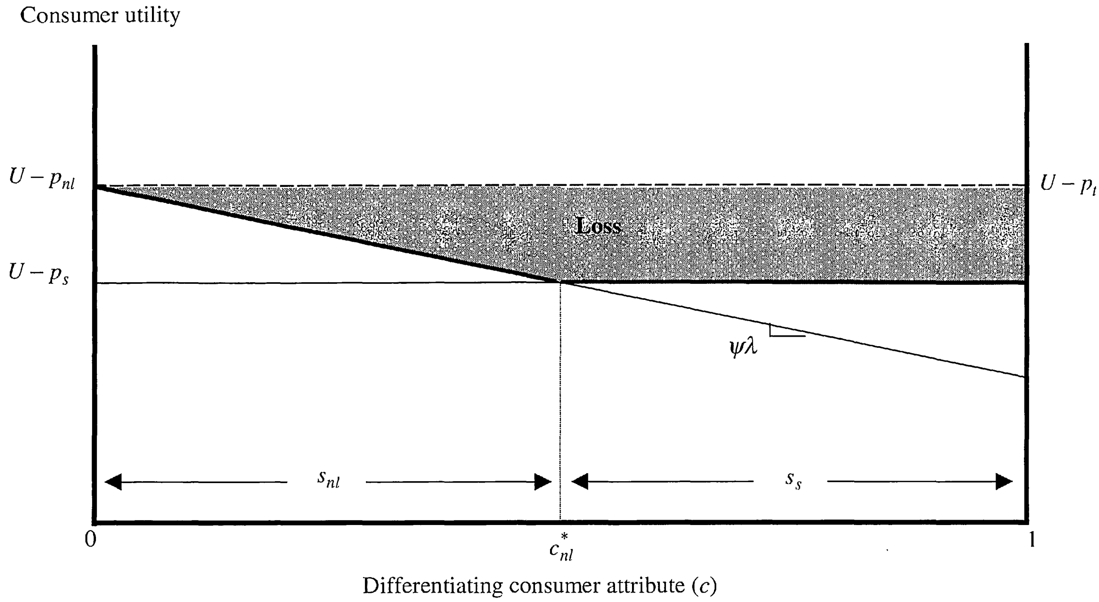

Fig. 2. Consumption decisions and welfare effects under GM and no labelling.

and

$$s_{\mathrm{s}} = 1 - \frac{p_{\mathrm{s}} - p_{\mathrm{nl}}}{\psi\lambda}$$

Fig. 2 graphs the determination of s_{nl} and s_{s}. The downward sloping curve graphs the utility associated with the unit consumption of the non-labelled product for different levels of the differentiating attribute c, while the (continuous) horizontal line shows the utility derived from the consumption of the substitute. The dashed $U - p_{\mathrm{t}}$ curve is the utility curve prior to GM. Thus, Fig. 2 is constructed on the assumption that the price of the non-labelled product equals the price of the traditional product, i.e. $p_{\mathrm{nl}} = p_{\mathrm{t}}$.

The intersection of the two (continuous) utility curves determines the level of the differentiating attribute that corresponds to the indifferent consumer, c^*_{nl}, as well as the consumption shares of the non-labelled product and the substitute. Consumers 'located' to the left of c^*_{nl} purchase the non-labelled product while consumers located to the right of c^*_{nl} find it optimal to consume the substitute. Consumer welfare under no labelling is given by the area under the effective utility curve shown as the bold kinked curve in Fig. 2.[6]

Comparative statics results can easily be drawn from this model. More specifically, a decrease in the price of the non-labelled product shifts the U_{nl} curve upwards and increases s_{nl} while an increase in the price of the substitute causes a downward shift of the U_{s} curve that increases s_{nl} (i.e. $\partial s_{\mathrm{nl}}/\partial p_{\mathrm{nl}} < 0$ and $\partial s_{\mathrm{nl}}/\partial p_{\mathrm{s}} > 0$). Finally, an increase in λ (i.e. an increase in the utility discount from consuming GM product for any level of c) and/or an increase in the likelihood that the non-labelled product is genetically modified, ψ,

[6] Relaxing the assumption that the substitute product (e.g. butter and potato chips in the examples above) remains free of GM ingredients would result in a clockwise rotation of the utility curve associated with its consumption through the intercept at $U - p_{\mathrm{s}}$ in Fig. 2. Similar to the case of the non-labelled product, the slope of the new utility curve for the substitute product would be determined by the utility discount factor λ, and the share of the GM version of the substitute product to its total production. Obviously, genetic modification of the substitute product reduces consumer welfare and increases the consumption share of the non-labelled product (i.e. margarine and corn chips) relative to the case where the substitute (i.e. butter or potato chips) remained in its conventional form.

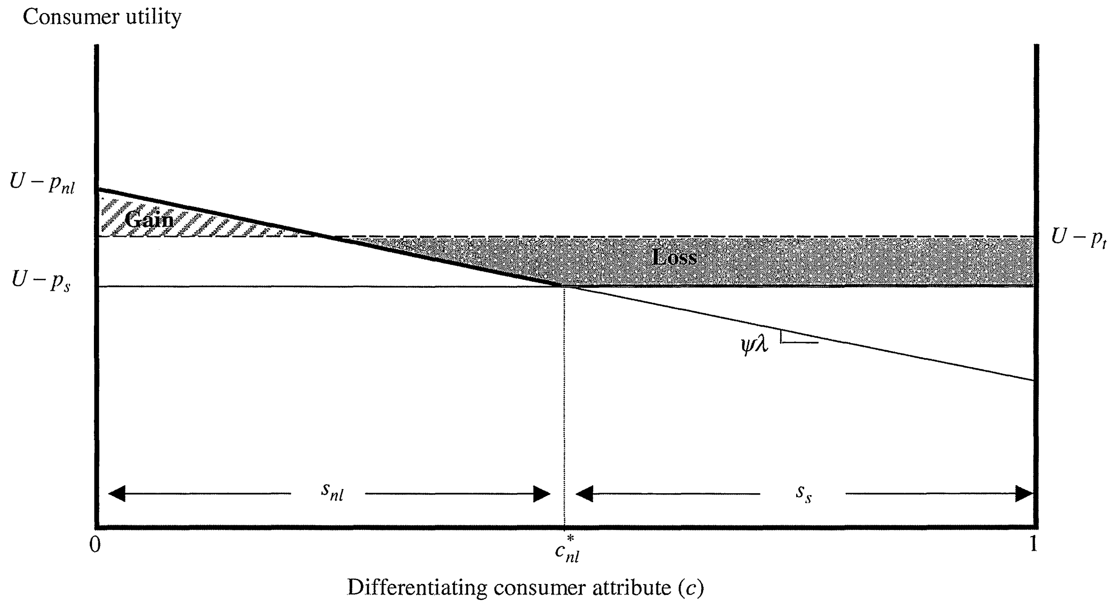

Fig. 3. Welfare effects when GM reduces the market price ($p_{\mathrm{nl}} < p_{\mathrm{t}}$).

cause a clockwise rotation of the U_{nl} curve through the intercept at $U - p_{\mathrm{nl}}$ that reduces the share of the non-labelled product to total consumption (i.e. $\partial s_{\mathrm{nl}}/\partial\lambda < 0$ and $\partial s_{\mathrm{nl}}/\partial\psi < 0$).

The effect of GM on consumer welfare depends largely on the effect of the technology introduction on the market price of the non-labelled product. The effect of GM on the final price of the product determines whether there will be any gains for consumers as well as the extent of losses due to consumer aversion to GM technology.

More specifically, if the existence of market imperfections in one or more stages of the food chain prevents the transmission of the cost savings to the consumers, the price seen by consumers is not affected by GM. As was noted earlier, Fig. 2 is constructed on the assumption that the price of the non-labelled product remains unchanged, i.e. $p_{\mathrm{nl}} = p_{\mathrm{t}}$. Under this assumption, the introduction of GM products leads to a loss in welfare to consumers in aggregate. This loss in welfare is given by the hatched area. Although the consumers located at $c = 0$ experience no loss in welfare, all consumers located to the right of this point see their utility fall. The extent of the realised welfare loss depends on the level of consumer aversion to GM products c, the utility discount factor λ, and the likelihood that the non-labelled product is GM, ψ.

If the production costs savings due to GM are transmitted to consumers (i.e. in the case of a perfectly competitive food chain), GM technology reduces the price of the product relative to its price prior to GM, p_{t}, and consumers with relatively low level of GM aversion will realise an increase in their welfare. Consumers with relatively high aversion to GM product experience a reduction in their welfare since the price effect of GM is outweighed by the utility discount from GM product consumption. Fig. 3 graphs the effect of GM on consumer welfare when $p_{\mathrm{nl}} < p_{\mathrm{t}}$.

The analysis can be easily modified to examine cases where consumers are not uniformly distributed with respect to their value of c but, rather, are lumped at either end of the continuum. For instance, when consumers do not perceive GM products as being different from their conventional counterparts (i.e. when $c = 0$ for all consumers), the introduction of the new technology will either leave the welfare of consumers unaffected (case where $p_{\mathrm{nl}} = p_{\mathrm{t}}$, Fig. 2), or will make all consumers better off (case where $p_{\mathrm{nl}} < p_{\mathrm{t}}$, Fig. 3). On the other hand, when the aversion of all consumers is relatively high (i.e. when $c = 1$ for all consumers), GM will cause consumer welfare to fall. More generally, when the distribution of consumers is continuous (but not uniform), the welfare effects of GM depend on its skewness, i.e. the more skewed is the distribution towards 1, the greater are the losses and the lower are the gains (when $p_{\mathrm{nl}} < p_{\mathrm{t}}$) from the introduction of the new technology.

Overall, the results of this section show that GM technology and no labelling may result in some consumption switching to the substitute good and a net welfare loss. If the number of consumers experiencing a welfare loss is substantial, a ban could be both rational and welfare improving. For net consumer losses to be realised it must hold that: (i) the price decrease from GM (if any) is relatively small; (ii) the discount in utility from consuming the GM product is relatively high; (iii) the likelihood that the non-labelled product is genetically modified is relatively high; and/or (iv) consumers are concentrated at the right hand edge of the aversion spectrum.

4. Consumer behaviour with mandatory labelling and full compliance

Consider now the consumer choice problem in an institutional arrangement with a mandatory labelling regime in place. In this case, traditional (non-GM) and GM products are segregated and marketed separately. Consumers now have a choice between a non-GM labelled product, its GM labelled counterpart, and a substitute product.[7] Consumer utility is given by:

$U_{\mathrm{t}}' = U - p_{\mathrm{t}}'$

if a unit of non-GM labelled product is consumed,

$U_{\mathrm{gm}} = U - p_{\mathrm{gm}} - \lambda c$

if a unit of GM labelled product is consumed,

and

$U_{\mathrm{s}} = U - p_{\mathrm{s}}$

if a unit of a substitute product is consumed

where p_{t}' is the price of the traditional product after the introduction of the new technology. All other variables are as previously defined.

The GM product and the non-GM product are not necessarily priced the same. In fact for any (positive) quantity of the GM labelled product to be demanded (i.e. for U_{gm} to exceed U_{t}'), p_{gm} should be less than p_{t}'. There are two reasons why the GM product will be priced lower than its traditional counterpart. First, mandatory labelling means increased marketing and segregation costs. These transaction costs associated with identity preservation cause consumer prices to rise. The majority of these costs are incurred in the non-GM labelled product chain (Lindner, 2000), which, in turn, implies that consumers of the traditional product face a greater price increase.[8] Second, it is assumed that GM technology generates production cost savings at the farm level. Some, if not all, of the cost savings may be transmitted to the consumer of the GM product.

Not only do the existence of marketing and segregation costs imply that $U - p_{\mathrm{gm}} > U - p_{\mathrm{t}}'$, the size of these costs significantly affects the consumption shares of the products being examined. More specifically, the greater the marketing and segregation costs, the greater is the price increase of the non-GM labelled product (relative to the price of the product prior to GM, p_{t}), and the lower is the utility associated with the unit consumption of the non-GM labelled product, U_{t}'. For relatively high marketing and segregation costs, the utility from consuming the non-GM labelled product might fall below the utility

[7] While the analysis assumes that both GM and traditional products are legally required to be labelled, the results are more general and apply to the case where only the GM or the traditional product has to be labelled. Specifically, when only traditional products are labelled, unlabelled products will be perceived as GM products. Similarly, if GM products are legally required to be labelled as such, unlabelled products will be perceived as being traditional. This symmetry does not hold, of course, when labelling is voluntary. With voluntary labelling, the labelling of a product as GM does not imply that non-labelled products are traditional in nature. Thus, suppliers of traditional food will always have incentives to label their produce as being traditional. Consumers would perceive products that are not labelled as traditional as being genetically modified.

[8] The labelling of one type of product would only affect the quantitative nature of the results by reducing the labelling costs in the supply chain of the product that would not have to be labelled. However, when any type of labelling occurs, traditional and GM products will have to be segregated. The segregation costs will always be higher for producers of the traditional product due to the effort required to preserve the identity of their produce by keeping it separate from the GM product that consumers regard as being inferior.

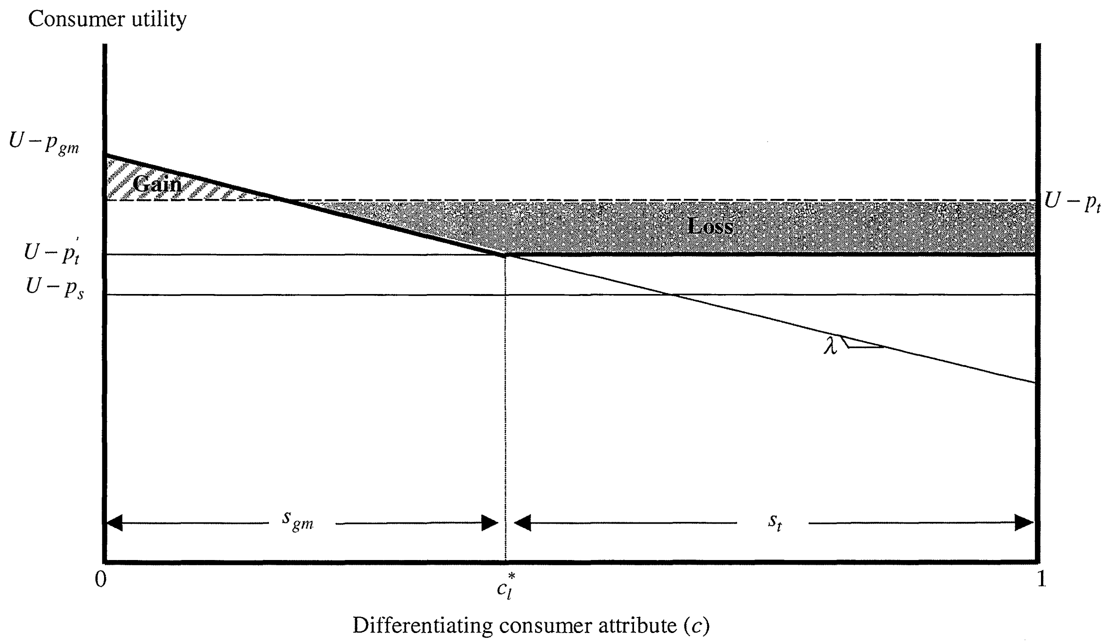

Fig. 4. Consumption decisions and welfare effects when segregation costs are relatively low ($U - p_t' > U - p_s$) and $p_{gm} < p_t$.

associated with the consumption of the substitute (i.e. $U - p_t' < U - p_s$). In such a case, consumers with a relatively high aversion to GM products will switch to the substitute product—there is no market demand for the traditional (non-GM) product.

Fig. 4 depicts the consumption decisions under mandatory labelling when marketing and segregation costs are relatively low (i.e. when $U - p_t' > U - p_s$). In this case, no consumer switches to the substitute. The consumption shares of the GM and non-GM labelled products are determined by the intersection of the U_{gm} and U_t' utility curves. The consumer with aversion to GM given by

$$c_l^* : U - p_{gm} - \lambda c_l^* = U - p_t' \Rightarrow c_l^* = \frac{p_t' - p_{gm}}{\lambda}$$

is indifferent between consuming a unit of GM and non-GM labelled product—the utility associated with the consumption of these offerings is the same. Consumers with low aversion to GM products (i.e. consumers with $c \in [0, c_l^*)$) prefer the GM product, while consumers with high aversion to GM products (i.e. consumers with $c \in (c_l^*, 1]$) consume the non-GM labelled product.

When consumers are uniformly distributed between the polar values of c, c_l^* also determines the share of the GM product in total consumption, s_{gm}. The consumption share of the non-GM labelled product, s_t, is given by $1 - c_l^*$, i.e.

$$s_{gm} = \frac{p_t' - p_{gm}}{\lambda} \quad (= c_l^*)$$

and

$$s_t = 1 - \frac{p_t' - p_{gm}}{\lambda}$$

Obviously, the share of the GM labelled product falls as its price and/or the utility discount factor increase, and rises as the price of the non-GM labelled product increases (i.e. $\partial s_{gm}/\partial p_{gm} < 0$, $\partial s_{gm}/\partial \lambda < 0$, and $\partial s_{gm}/\partial p_t' > 0$).

When the transaction costs from mandatory labelling are relatively high (i.e. when $U - p_t' < U - p_s$), some consumers switch to the substitute product. The consumption shares of the GM product and the substitute product are determined by the intersection of the U_{gm} and U_s curves (Fig. 5) and can be

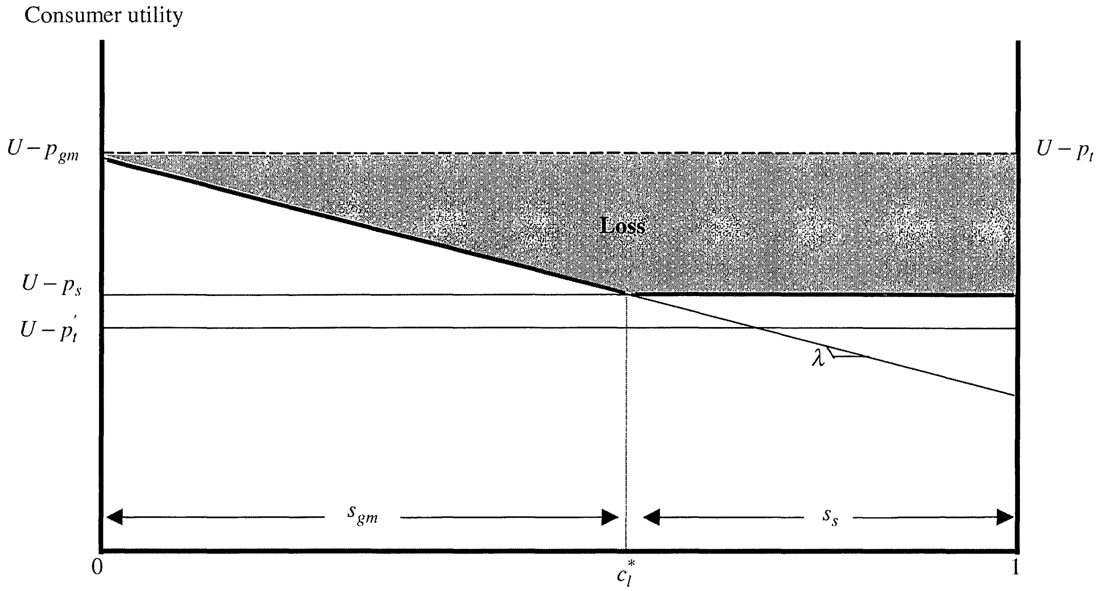

Fig. 5. Consumption decisions and welfare effects when segregation costs are relatively high ($U - p_t' < U - p_s$) and $p_{gm} < p_t$.

written as:

$$s_{gm} = \frac{p_s - p_{gm}}{\lambda} \; (= c_l^*)$$

and

$$s_s = 1 - \frac{p_s - p_{gm}}{\lambda}$$

Similar to the case of smaller marketing and segregation costs examined earlier, s_{gm} falls as p_{gm} and/or λ increase, and rises as p_s increases (i.e. $\partial s_{gm}/\partial p_{gm} < 0$, $\partial s_{gm}/\partial\lambda < 0$, and $\partial s_{gm}/\partial p_s > 0$).

The welfare effects of GM under mandatory labelling clearly depend on the effect of GM technology on the price of the GM product. More specifically, if the price of the GM product is less than the price of the product prior to its GM (i.e. if $p_{gm} < p_t$) consumers with relatively low aversion to GM product will gain from the new technology. Consumers with relatively high aversion to GM product experience a reduction in their welfare due to: (i) the utility discount from GM product consumption; and (ii) the price increase of the traditional product caused by the marketing and segregation costs. Note that for p_{gm} to be reduced relative to p_t, two conditions should be met. First, the market structure must be such that production costs savings from the GM technology are transmitted to consumers and, second, the effect of the reduced production costs on the market price of the GM product should outweigh the effect of increased transaction costs associated with mandatory labelling.

Fig. 4 graphs the effect of GM on consumer welfare when marketing costs are relatively low (i.e. $U - p_t' > U - p_s$) and $p_{gm} < p_t$. The dashed $U - p_t$ curve is the utility curve prior to GM. For net consumer gains to be realised it should hold that: (i) the price decrease from GM is relatively high, (ii) the discount in utility from consuming the GM product is relatively low, and/or (iii) the marketing and segregation costs are relatively low. A bunching of consumers at the left-hand edge or the right-hand edge of the diagram would increase the gain or loss, respectively.

More specifically, the greater the price reduction from GM, the greater the upward shift of the U_{gm} curve, the greater the consumer gains and the lower the welfare loss from the new technology. Similarly, the lower the λ, the greater the slope of the U_{gm} curve, the greater the gains and the lower the consumer losses from GM. Finally, the greater the marketing and segregation costs incurred in the non-GM product chain, the greater the downward shift of the $U - p_t'$ curve and the greater the consumer welfare losses from the new technology.

Fig. 5 depicts the welfare effects of GM when the transaction costs from mandatory labelling are relatively high (i.e. when $U - p_t' < U - p_s$) and $p_{gm} \geq p_t$. In this case, no consumers gain from the new technology. The extent of the realised welfare losses depends on the level of aversion to GM c, the utility discount factor λ, and the level of p_{gm}.

5. Consumer behaviour under mandatory labelling: the effect of mislabelling

This section of the paper analyses the consequences of mislabelling on consumer purchasing decisions and welfare. Mislabelling refers to the case where producers or processors misrepresent the type of the product sold in the market; they label GM products as non-GM (or in a case where only GM products are required to be labelled, they fail to label their GM products as such) in an attempt to capture the price premium paid for traditional (non-GM) produce.

When incidents of mislabelling occur in the food marketing system, consumer trust in labelling falls. Consumers can be expected to assign a probability to the event that what is labelled as 'non-GM' is in fact genetically modified. Because of the uncertainty regarding the nature of the product consumed, the utility derived from the consumption of the non-GM labelled product, U_t^m, equals $\theta[U - p_t' - \lambda c] + (1-\theta)[U - p_t']$, where θ is the likelihood that the non-GM label is false and the product is actually genetically modified.[9]

Taking into account this uncertainty, the consumer utility under mislabelling becomes:

$$U_t^m = U - p_t' - \theta\lambda c$$

if a unit of non-GM labelled product is consumed,

$$U_{gm} = U - p_{gm} - \lambda c$$

if a unit of GM labelled product is consumed,

and

$$U_s = U - p_s$$

if a unit of a substitute product is consumed.

Relative to the situation of full compliance examined in the previous section, product misrepresentation results in a discount in the utility associated with the consumption of the non-GM labelled product. Graphically, this utility discount can be seen as a clockwise rotation of the utility curve associated with the non-GM labelled product through the intercept at $U - p_t'$ in Figs. 5 and 6.

Consider first the case where marketing and segregation costs are relatively low (i.e. $U - p_t' > U - p_s$). Compared to the case where mislabelling does not occur, mislabelling reduces both consumer welfare (shaded area in Fig. 6) and the consumption share of the non-GM labelled product. Some of the (previously) non-GM labelled product consumers (i.e. those with $c \in (c_l^*, c_1]$) switch to the GM labelled product while consumers with a relatively high level of c (i.e. consumers with $c \in (c_2, 1]$) switch to the substitute. The greater the probability θthat the non-GM label is false and/or the greater the utility discount from the consumption of GM products, λ, the greater the welfare losses from mislabelling and the greater the share of non-GM product consumers that switch to the GM product and the substitute.

In the presence of mislabelling, the consumption share of the GM labelled product, s_{gm}, equals c_1, the share of the non-GM labelled product, s_t, equals $c_2 - c_1$, while $1 - c_2$ percent of consumption moves to the substitute. Mathematically, the consumption shares can be written as

$$s_{gm} = \frac{p_t' - p_{gm}}{\lambda(1-\theta)} \quad (= c_1)$$

$$s_t = \frac{p_s - p_t'}{\theta\lambda} - \frac{p_t' - p_{gm}}{\lambda(1-\theta)} \quad (= c_2 - c_1)$$

and

$$s_s = 1 - \frac{p_s - p_t'}{\theta\lambda} \quad (= 1 - c_2)$$

When the marketing and segregation costs are relatively high (i.e. when $U - p_t' < U - p_s$), then mislabelling, as opposed to full compliance, has no effect on either welfare or the consumption decisions of

[9] Note that the consumer utility when the non-GM labelled product is GM is given by $U - p_t' - \lambda c$ (rather than $U - p_{gm} - \lambda c$) since the price paid for the consumption of the product is p_t' (and not p_{gm}).

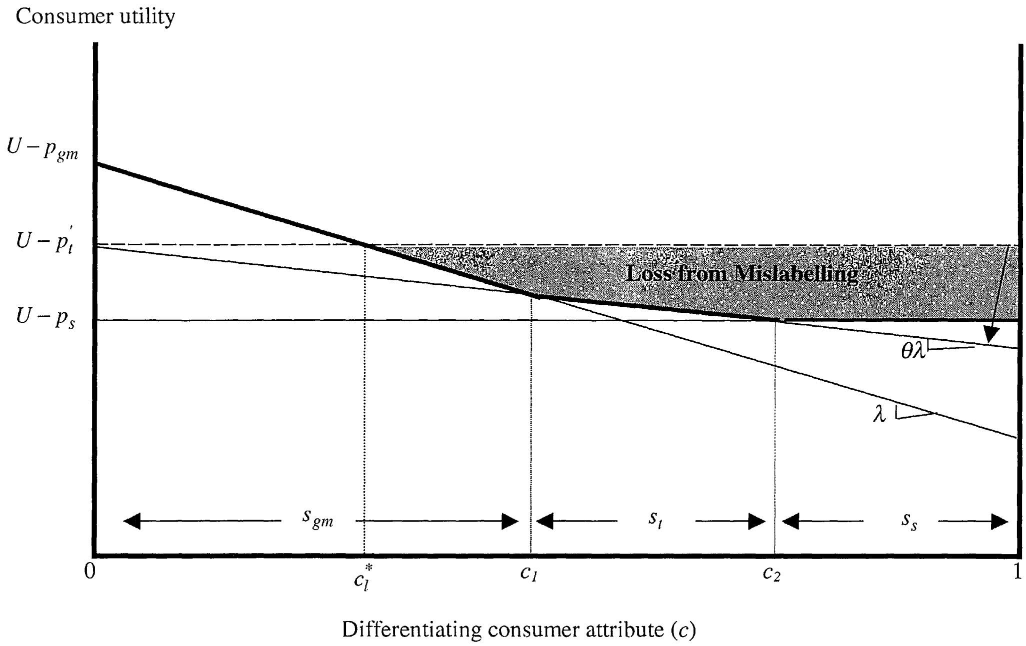

Fig. 6. Consumption and welfare effects of mislabelling when segregation costs are relatively low ($U - p_t' > U - p_s$).

consumers since in this case no traditional (non-GM) product is consumed (Fig. 5).

6. No labelling versus mandatory labelling

After having analysed the consumption effects of GM technology under the 'no labelling' and 'mandatory labelling' regimes, the question that naturally arises is which labelling regime dominates in terms of its effect on consumer welfare. Or put in a different way, since the introduction of GM products can result in net welfare losses under both the 'no labelling' and the 'mandatory labelling' regimes, what regime harms consumers the least?

The determination of the factors affecting the relative performance of the two labelling regimes is straightforward. Fig. 7 shows the effective utility curves under no labelling (dashed kinked curve) and mandatory labelling under full compliance (solid kinked curve) when the marketing and segregation costs are relatively low. For simplicity and without loss of generality Fig. 7 depicts the situation in which the price of the non-labelled product p_{nl} equals the price of the GM labelled product p_{gm}.

The shaded area NL reflects consumer utility under the no labelling regime that is lost when mandatory labelling is introduced. Similarly, the area ML represents consumer utility that is lost from a switch from mandatory labelling to no labelling. Obviously, consumers located to the right of c^+ will favour mandatory labelling, while for consumers located to the left of c^+ no labelling is the preferred labelling regime. The ranking of the labelling regimes in terms of their net effect on consumer welfare depends on the relative size of the shaded areas in Fig. 7; if NL is greater than ML, then no labelling is the superior regime. Obviously, when the assumption of a uniform distribution of consumers is relaxed, the welfare ranking of the two labelling regimes is affected by the skewness of the distribution. In general, the greater the number of consumers that are characterised by a relatively high aversion to GM products (i.e. the more skewed towards one is the distribution of consumers with respect to their value of c), the greater the likelihood that mandatory labelling is the preferred labelling regime.

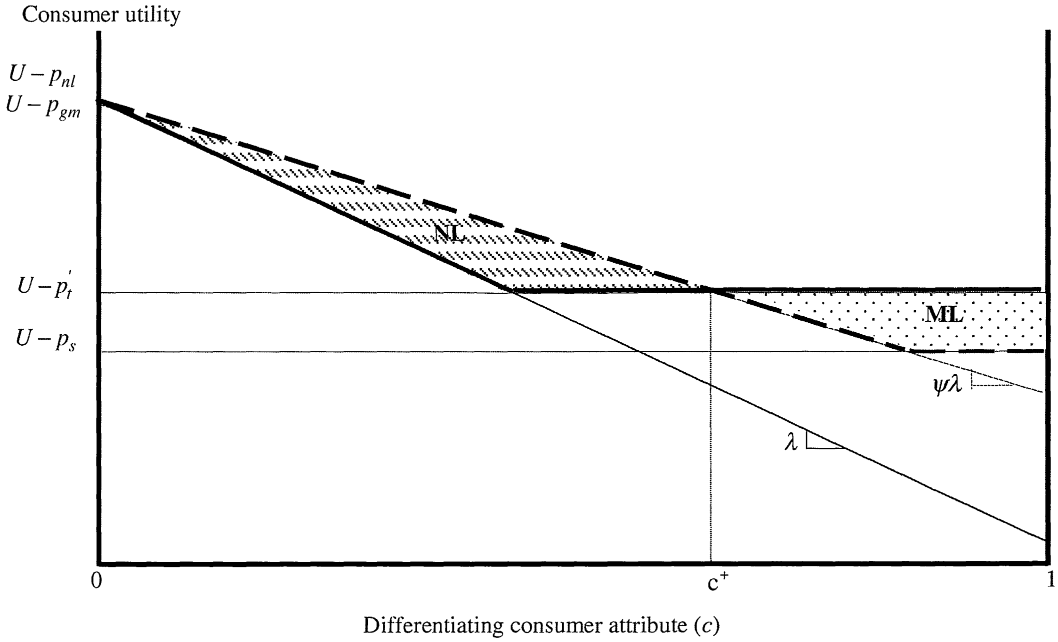

Fig. 7. Mandatory labelling vs. no labelling when segregation costs are relatively low ($U - p_t' > U - p_s$).

Comparative statics results can easily be derived from Fig. 7. For instance, an increase in the likelihood that the non-labelled product is GM (i.e. an increase in ψ) causes a clockwise rotation of the U_{nl} curve ($U_{nl} = U - p_{nl} - \psi\lambda c$) that increases ML and reduces NL. The greater is ψ, the greater is the consumer support for mandatory labelling. Similarly, an increase in the marketing and segregation costs associated with mandatory labelling will shift the $U - p_t'$ and $U - p_{gm} - \lambda c$ curves downward increasing NL and reducing ML. The greater the marketing and segregation costs, the greater the proportion of consumers favouring no labelling; when marketing and segregation costs are relatively high (i.e. when $U - p_t' < U - p_s$) the area ML vanishes and no labelling is the superior regime.

Finally, when the assumption of full compliance is relaxed and the possibility of product misrepresentation is introduced, the mandatory labelling regime becomes even less appealing from the consumers' standpoint; mislabelling increases the likelihood that no labelling is superior in terms of its effects on total consumer welfare. The greater the probability that mislabelling occurs, the greater the consumer utility losses under mandatory labelling, and the greater the likelihood that an all-or-nothing choice between the two labelling regimes in terms of their effect on consumer utility will favour no labelling.

7. Concluding remarks

This paper develops a model of differentiated consumers to examine the effects of GM technology on the welfare and purchasing behaviour of consumers. The conclusion of this paper is that if consumers perceive GM products to be different from their traditional counterparts, then demands for the banning of GM products and GM labelling are rational. For instance, when the existence of market imperfections in one or more stages of the supply chain prevents the transmission of the cost savings associated with the GM technology to consumers, then the introduction of GM products will generally result in welfare losses for consumers. This is true regardless of the labelling regime that is in place.

Given that GM products have been introduced into the food system, the analysis also shows that the relative welfare ranking of the 'no labelling' and 'mandatory labelling' regimes depends on: (i) the level of consumer aversion to GM products, (ii) the segregation costs associated with mandatory labelling; (iii) the share of the GM product in total production; and (iv) the extent of mislabelling. More specifically, the greater the segregation costs associated with mandatory labelling, the greater the likelihood that no labelling is the superior labelling regime. The greater the likelihood that the non-labelled product is GM, the greater the likelihood that mandatory labelling will be preferred.

Finally, when the possibility of product mislabelling is introduced into the analysis, the desirability of mandatory labelling by consumers falls. The uncertainty about product characteristics due to mislabelling reduces consumer welfare and drives some non-GM product consumers out of the market. The lower the level of trust in the labelling system, the greater the expectation that mislabelling occurs, the greater the consumer utility losses under mandatory labelling, and the greater the likelihood that an all-or-nothing choice between the two labelling regimes in terms of their welfare implications favours no labelling.

The results of this paper can provide an explanation for policy decisions about GM technology and labelling observed around the world. Relatively low (or zero) consumer aversion to genetic engineering coupled with a reduced price of GM products and significant segregation costs associated with mandatory labelling could be among the reasons why a 'no labelling' policy has been adopted by countries such as the US and Canada. Increasing consumer concerns, however, and the relatively high level of consumer trust in the food safety institutions in both countries could increase the relative efficiency of, and hence the consumer demand for, mandatory labelling.

A relatively high aversion to GM technology coupled with a lack of a price reduction for GM products would rationalise mandatory labelling, an outcome seen in various EU countries. However, a high level of distrust of food safety and inspection systems can undermine the value of labelling. This result sheds light on the demand for an outright ban of GM products by some European consumers, since faith in the food inspection systems there has been reduced by food safety scares such as the Bovine Spongiform Encephalopathy (BSE) crisis in the British beef industry.

In summary, consumer concerns about GM products can be expected to affect consumption decisions and to influence the public policy response demanded by consumers. These consumption decisions, along with the decisions made by policy makers as to how GM products are introduced into the food system, can have significant impacts on the demand for GM products throughout the food system. These system effects, in turn, will affect the decisions made by farmers as to which crops they grow as well as decisions made by life science companies as to the pricing and the development of GM technologies.

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