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An integrated consumer and supply chain risk analysis of genetic modification in livestock production chains

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Abstract

This article presents an integrated consumer acceptance and supply chain risk analysis of genetic modification in livestock production chains. In general, results provide insight into feasibility of certain GM applications to be incorporated into pork chain. Overall, livestock producers can expect a cost reduction. Moreover, with the heterogeneous nature of consumer preferences there are some segments that wholly respond on the integration of different GM applications in the chain. However, in some cases, it is difficult to say whether the chain can respond to consumers' requirements.

Introduction

Public acceptance of genetic modification in livestock products is generally even more difficult than in areas such as crop production, both from a technical and an ethical perspective. However, it holds considerable promise for producers and consumers. Producers may profit from an enhanced growth performance of animals and from reduced production costs, e.g. feeding, and manure costs. Consumer benefits may be found in an increased quality of meat (less fat, lower residues) and lower prices (de Vries, et al., 2000; Solomon, et al., 1997). Additionally, society as a whole may benefit from a reduced environmental impact (reduction of phosphorus emission) and improved animal welfare (Bonneau and Laarveld, 1999).

Economic effects of introducing certain types of GM applications in the chain are generally analyzed partially, e.g. at the farm level (Chung and Pettigrew, 1998).

‘Economics’ (if any) mostly refer to specific participants of the production chain (see for instance Visscher, et al., 2000) and do not consider risk, nor consumer behavior. However, new technology has an impact on the chain as a whole and should therefore be analyzed from a chain perspective. Even more, since the use of GM applications is likely to influence consumer behavior, an economic analysis of GM applications should also consider consumer preferences. Nevertheless, in current studies an integrated chain approach is missing.

The purpose of this article is to perform an integrated consumer acceptance and supply chain risk analysis of genetic modification in livestock production chains. More specifically the aim is (1) to analyze consumer acceptance towards four main chain GM applications (GM animal, GM feed, GM medicines & additives and GM bacteria); (2) to derive technical and economic data on feasible GM applications (3) to combine obtained consumer and technical data in an integrated chain simulation model. This article focuses on GM applications in pork production chains in the Netherlands. Technical data is analyzed for breeding, growing and fattening stages.

GM applications and sub-applications in livestock production chains

GM applications: Genetic modification can be applied for many purposes e.g. medication, test-models, production. The latter is described in this paper. Four types of genetic modification were selected to cover the whole livestock production chain. These applications were GM animal, GM feed, GM medicine & additives and GM

bacteria. GM animal referred to a GM pig with modified genes (farrowing stage). GM feed presented feed/crops that were produced with help of gene technology (farrowing and fattening stages). GM medicine & additives referred to the medicine (antibiotics, vaccines) and additives (phytase, vitamins) that were produced with help of genetic modification (farrowing and fattening stages). GM bacteria was defined as bacteria produced with help of genetic modification and used to preserve meat (processing/slaughtering stage).

Sub-applications for technical analysis: Per each GM type three concrete sub-applications were chosen for the analysis (Table 1). GM bacteria were left out from the analysis. Sub-applications are grouped along with the party they are expected to be beneficial for (producer, society, and consumer). These sub-applications aim at different benefits important to producer, society and consumers. Regarding producer benefits these sub-applications decrease production costs by improving animal performance, reducing feed costs. Sub-applications relevant to "society" reduce impact of the pork production on the environment by lessening the excretion of phosphorus in manure. Last group of sub-applications important to consumers aims at production of (healthier) leaner meat (Spinach gene), reduction of use of antibiotics (Edible vaccines) and improvement of animal welfare (Immunocastration).

Materials and methods

Consumers: Consumer data was collected by means of a written questionnaire. Respondents were selected from 26 regions across the country. After two weeks a reminder was send. The important part of the questionnaire was a choice experiment. Choice experiment is often used to estimate the importance of various product attributes with different levels for consumer choice (Adamowicz, et al., 1998; Adamowicz, Louviere and Swait, 1998; Louviere, 1991). In other words, the idea behind choice experiments is that consumers can choose between alternative options that are composed of attributes with different levels. Consumers were presented with several choice scenarios combined of four genetic applications (GM animal, GM feed, GM medicine & additives and GM bacteria) with varied benefits (improvements in quality, animal welfare, environment, reduced residues and prices). Throughout the questionnaire, four types of GM applications were presented in terms of easy understandable, i.e. non-technical, scenarios that cover multiple stages and consumer concerns/benefits. By means of nested logit model the importance of benefits and preferences for different GM applications were analysed. Furthermore, based on the data of the choice experiment a cluster analysis is performed. Before identifying the number of relevant segments for the analysis, consumers who have constantly selected option three (conventional pork) for all sixteen choice sets were assigned to a special "non-gm segment". Further segmentation was based on 2544 choice sets. Based on the best representation of

data for which the information statistics reach minimum we have selected five-segment solution (including segment selected before).

Technical and economic data: Experts' panel was used to collect necessary technical and economic data on the selected GM applications. Experts were selected depending on the area of their expertise; these were nutritionists, animal physiologists, animal and plant breeders, veterinarian, and representatives of feed industry. The interviews were performed on a face-to-face basis. Firstly, before discussing GM applications with the experts, the scientific literature on the topic was reviewed. We selected several technical parameters (such as average growth rate, feed conversion ratio, litter size) that are possible to change due to application of GM, and linked them to the chain parameters. Moreover, from the scientific results, the possible ranges of the expected effects were identified. Secondly, these effects were discussed with selected experts. Experts had to analyze results obtained from the scientific literature and then provide their personal estimates (if it was possible) on the effects of sub-applications. Experts could hardly respond to a wide range of uncertainty of some GM applications that do not exist yet. In expert's view information/number extracted from the scientific literature are somewhat different for the Dutch case. Most research articles describe experiments performed in the USA, using for example special feed diets that are quite different from what is used in the Netherlands.

Simulation model: The choice of using simulation model was supported by (1) absence of the "real" data for application of GM in the chain (2) the necessity to incorporate risk/uncertainty into the chain. Figure 1 presents the approach used to analyse chain and consumer response on incorporation of different GM applications.

In order to analyze changes in (the distribution of) costs, revenues and risks throughout the pork production chain first a Monte Carlo simulation model of the default situation is developed. The model includes farrowing, growing and fattening stages of the pork production chain. For each participant the model includes the main economic activities. Integrated Chain Control agreements are used as the default for animal welfare, environmental, food safety, traceability and GM-requirements. Model *input* consists of (the probability distributions of) costs and revenues for the various activities (for example feed costs, prices of hogs/piglets). Data originate from literature and existing developed pork chain models (den Ouden, 1996). Model *output* involves the distribution of costs, revenues along the stages of the chain.

After having analyzed the default situation, the impact of GM applications is simulated. Model *input* on one side consist of technical and risk data for the alternative GM applications that originate from literature and expert opinions, on the other side it composed of relevant costs of production. Costs of production (in situation when GM is applied) are taken in the aggregated manner since it is difficult to perform a detailed analysis like partial budgeting.

The economic and technical data of alternative situation (a specific GM application) is compared with a basic situation (no GM). Furthermore, since the model also considers risk, the comparison between basic situation and alternative is extended by incorporating probability distributions around the various categories. Risk analysis was incorporated using the @Risk package to obtain a range of results for economic and technical parameters. In this analysis we use the triangular probability distribution (minimum, most likely, maximum).

After having compared basic situation with alternative chain, results are matched with the data on general consumer preferences, willingness-to-pay and various segments that have been identified in the previous related study.

Results

Consumers: During autumn 2004 a survey was conducted in The Netherlands. In total 253 complete questionnaires were returned (11% response rate). Low response rate was expected due to the difficulty of the topic and specificity of addressing random respondents in the Netherlands.

The average age of the respondents was 50.5 years (s.d. 14.3), of whom 53% where female. The sample was representative of the Dutch population only regarding gender. The sample was not representative with respect to age, household size, number of children in household and education level, with more highly educated respondents and households of two persons and without children over-represented.

In general, results indicate that consumers prefer conventional pork over pork for which genetic modification was applied (Figure 2). Less negative attitude consumers express to pork fed GM feed (utility for this applications is equal to -0.0038), followed by GM bacteria, GM animal and GM medicines & additives with almost the same negative utility (utility coefficients for these application range from -0.3848 to -0.4246). However, the negative impact of the GM applications can be compensated by improvements in quality, increased animal welfare, a lower impact on the environment, less residues and a price discount. Increased animal welfare has the most positive effect on consumer choices. With monetary compensation (for some applications up to 30%) and presence of one or several various benefits the consumers will have higher preferences to the GM pork than to the conventional pork. The amount of compensation is dependent on the type of GM application.

In addition to this analysis, we identified five consumer segments. Examination of the estimated utilities of each segment indicates that consumers in each segment value product benefits and GM applications very differently (Table 2).

The first segment presents 12.4% of consumers. In this segment consumers are positive about two GM applications, GM animal and GM feed; GM additives & medicines and GM bacteria have a negative influence on the consumers' choice. Regarding benefits, price reduction and improvements in animal welfare have a strong influence on the consumers' choice. Reduced impact on the environment and residues do not interest these consumers.

The second segment is about the same size as the first one, it contains 12.1% of consumers. In the second segment consumers are in general negative about GM and presence of the benefits does not play an important role. None of the four applications have a positive sign.

The third segment is the smallest segment; its size is 9.1% Consumers of the third segment are "against" GM (all GM applications have negative coefficients). Consumers are especially negative towards GM animal, followed by GM feed. GM additives and GM bacteria perceived less negatively. However, offered benefits do interest consumers in this segment. The third-segment consumers have the same positive attitude to the price reduction as consumers in the first segment. It seems that improvements in animal welfare and reduced residues have an important positive influence on the consumer's utility. These two benefits in the third segment have the highest coefficients compared to the same benefits in the other segments.

The forth segment represents about 29.1% of the respondents. The positive and high utilities for all GM applications indicate that consumers are positive about genetic modification being used in pork production. Presence of GM bacteria has the strongest influence on the consumer choices. The respondents in this segment appear to like new benefits. Compared to the respondents in other segment consumers in this segment are price sensitive (the utility coefficient for price discount is much higher compare to other segments); improvements in all pork characteristics have a significant positive influence on consumer choices.

The last, fifth segment is the largest segment in our sample (37.1%). It contains consumers who did choose for all sixteen choices the "conventional option". It means that these consumers do not accept GM pork at all, no matter what kind of modification was applied and what kind of benefits this pork can offer to the consumers.

Simulation model: The preliminary model results provide insight into the impact of specific GM applications on (the distribution of) costs, revenues and risks throughout the pork production chain, and into the effect on consumer prices. Overall, livestock producers can expect a cost reduction. Moreover, with the heterogeneous nature of consumer preferences there are some segments that wholly respond on the integration of different GM applications in the chain. However, in some cases, e.g. GM medicine, it is difficult to say whether the chain can respond to consumers' requirements (overwhelming price discounts and presence of all benefits which is not compensated by the possible costs reduction in the chain).

Discussion/Future outlook

Results of this article help to analyze how to restructure the chain in order to embrace economically beneficial GM applications, taking into account consumer preferences and possible risks throughout the chain.

Genetic modification is a very timely and important topic for agricultural developments and supply chains. Especially this is true with respect to

internalizations of supply chains, growing number of co-existing studies, rapidly changing regulations and requirements of current General Food Law. Existing and emerging requirements of traceability and labelling practices entail to analyze genetic modification from a definite chain perspective.

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Table 1. GM applications and sub-applications

	Producer	Society	Consumer
GM animal	Bovine gene	Enviropigs	Spinach gene
GM feed	GM crops	Phytase in plants	Edible vaccines
GM feed additives & medicine	Antibodies	Microbial phytase	Immunocastration

Table 2. Parameter values for latent class model

	Segment1 (12.4%)	Segment 2 (12.1%)	Segment 3 (9.1%)	Segment 4 (29.3%)	Segment 5 (37.1%)
Benefits					
1% price discount	**0.020058*** **	0.001589	**0.022102** **	**0.024700*** **	
	(0.005514)	(0.006663)	(0.007520)	(0.003248)	
Improved quality	**0.346285** **	-0.019694	**0.455203** **	**0.459942*** **	
	(0.126460)	(0.161923)	(0.174693)	(0.067795)	
Improved animal welfare	**1.128646*** **	0.189918	**1.768976*** **	**0.940353*** **	
	(0.139707)	(0.190942)	(0.242964)	(0.081757)	
Improved environment	0.016726	0.073029	0.299829	**0.171121* **	
	(0.135059)	(0.190228)	(0.217712)	(0.079742)	
Reduced residues	0.175606	0.061329	**1.063284*** **	**0.567016*** **	
	(0.124543)	(0.161809)	(0.188806)	(0.068799)	
GM applications					
GM animal	**2.916499* **	**-1.980279*** **	**-7.066894*** **	**2.755035*** **	NON-GM segment
	(1.025884)	(0.289915)	(0.807631)	(0.718208)	
GM feed	**2.204935* **	**-0.728532** **	**-2.271653*** **	**2.370548*** **	
	(0.745458)	(0.270725)	(0.403859)	(0.590423)	
GM additives & medicines	**-2.340122* **	**-2.825693*** **	-0.305343	**2.817286*** **	
	(0.259652)	(0.340246)	(0.567543)	(0.730092)	
GM bacteria	**-1.993105* **	**-1.374436*** **	**-0.946450** **	**3.211059*** **	
	(0.229313)	(0.236282)	(0.308080)	(0.645139)	

*$P < 0.05$, ** $P < 0.01$, *** $P < 0.001$

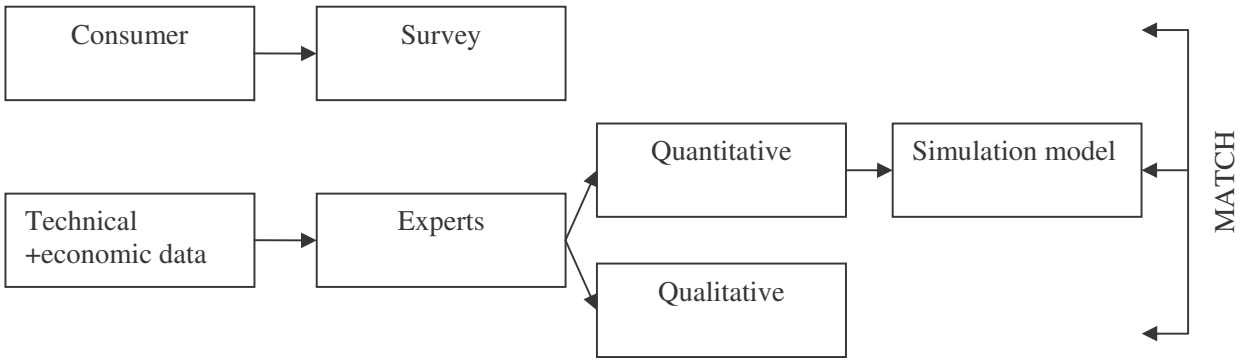

Figure 1. Schematic outline of research approach

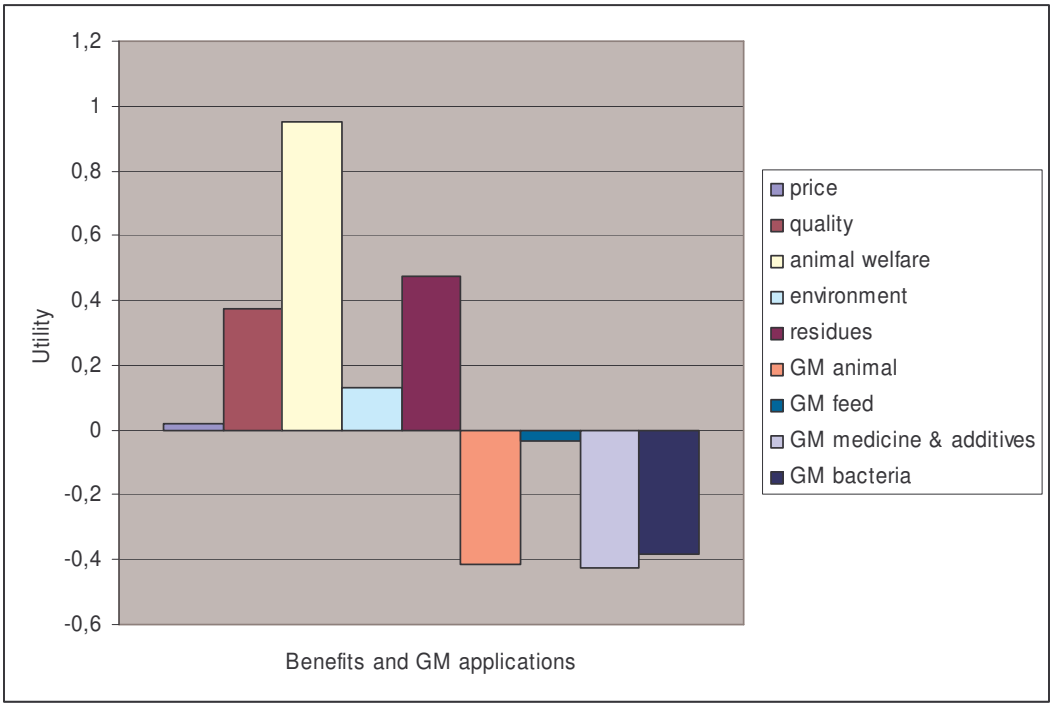

Figure 2. Consumer's utilities of benefits and specific GM applications