Impact Evaluation of Food Safety Regulations: A Review of Quantitative Methods

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1. Introduction

Recently regulatory evaluation performed by the European Commission has been reviewed in response to the call for more evidence-based policy making and "Better Regulation", which requires instruments to support the adoption of more effective and efficient regulations, as well as an improved coordination of policy interventions across the economic, social and environmental dimensions (European Commission, 2002). At the same time, there is a demand for clarity in the methods used to evaluate the impacts of regulations. While there is an ongoing debate on the methodological frameworks that are or could be used to assess the overall impact of regulations, our focus here is on the quantitative techniques that measure the economic effects and estimate the monetary values of non-market effects. This is especially relevant in policy areas like that of food safety, where a wide variety of alternative techniques are used to measure the same impact, often with very different or even conflicting results. Food safety regulations generate different effects to different economic actors along the food chain, covering more than a policy area, like health protection, competition, trade and environment.
The aim of this study is to review and discuss the quantitative methodologies applied to assess the socio-economic impacts of food safety regulations in a selection of studies found in the literature available to date[1]. The paper is structured as follows. First, we propose a classification of potential impacts relevant in food safety regulations, based on the European Commission Impact Assessment Guidelines (2005). Then, we associate each impact with the methodologies used in the literature. An overview of the methodologies is presented, highlighting strengths and weaknesses; methodologies not currently used but potentially exploitable in food safety regulatory assessments are briefly described. In the fourth section, we add further information about the evaluation studies, by specifying stage of assessment, level of analysis, type of data required, and geographical scope of analysis. Final considerations conclude the review.

2. Classification of impacts

Current impact assessment at the EU level is mainly based on the EC impact assessment guidelines (EC-IAG), developed in response to the call for "better regulation". The EC-IAG (2005, pages 29-32) identify a list of 32 potential impacts of a regulation, independently from the policy area. Here we propose a simplified classification based on the above, which we consider as complete with respect to the impacts of food safety regulations and allows a better correspon-

1. This study is part of the MoniQA Network of Excellence ("Towards the harmonisation of analytical methods for monitoring quality and safety in the food supply chain"), supported by the EC-Sixth Framework Programme, contract no. FOOD-CT-2006-036337 (http://www.moniqa.org). Specifically, it deals with Work Package 7 ("Socio-economic impact and cost efficiency"), whose main objective is to perform a systematic assessment of new EU food quality and safety regulations with respect to industry, control and regulatory bodies and regarding their socio-economic impacts in terms of efficiency, effectiveness and consistency, their administrative costs and their impact on international trade (www.moniqa.org/index.php?id=92142&lang=default).

dence with the quantitative methodologies found in the literature.
Our simplified and aggregate list includes 9 potential impacts of a food safety regulation. We review these impacts in relation with the quantitative techniques commonly employed for evaluation.

Public health and security. Safeguarding public health and reducing the risk of illnesses and the associated health costs are the primary objectives of food safety regulations. These health benefits are usually measured in the literature with the cost-of-illness (COI) approach or, alternatively, with direct elicitation methods for the willingness-to-pay (WTP), which include contingent valuation and experimental auction markets. Other methods, like general equilibrium studies (especially those based on the social accounting matrix), may exploit the obtained estimates of public health benefits as a component of the overall evaluation exercise.

Consumer and households. Beyond the public health effects, regulations have an impact on households and consumers. The introduction of food safety measures are likely to have an effect on prices, product quality and a variety of available products, ultimately affecting the way consumer choose their consumption basket and the overall household welfare. A few studies apply revealed preference methods, like hedonic pricing, and stated preference methods, such as conjoint analysis and other methods that estimate the willingness-to-pay. Other evaluation studies rely on microeconometric models (like demand and welfare analysis) which may feed in broader partial equilibrium and general equilibrium approaches.

International trade and third countries. When the objective is an assessment of the international trade effects of a regulation or the consequences on the economy of third countries whose trade is affected by the introduction of new measures, the quantification is based on macroeconometric models like the gravity model and non-parametric models.

Firm competition. New or modified regulations always play a role on market competition. National measures may affect the competitiveness of internal versus foreign businesses, and also internal competition, as they may generate market barriers that can ultimately lead to market failures (oligopolies, monopolies) or alter the market balances between firms of different economic sizes. These effects can be evaluated through either direct accountancy methods (e.g. cost of compliance), microeconometric models (profit production functions, quality-adjusted cost functions, etc.) and – on a broader scale – partial and general equilibrium studies based on linear programming models and/or input-output models (like the SAM approach).

Conduct of businesses. Regulations generate costs and benefits at the business levels. Operating and administrative costs can be evaluated – as before – through direct accountancy methods, microeconometric (cost function, binary logit regression equation), and equilibrium models. Difficult to estimate quantitatively are benefits that accrue to firms and plants, like improvements in shelf life, access to new markets such as export markets, retention of customers, decreased scrap or reworking of product, and reduced product liability. The liability costs method is an alternative route to quantification of potential benefits for firms of risk-reducing regulations. However, there are data reliability problems with this approach.

Innovation. Regulatory constraints may provide incentives or barriers to research and technological innovation. While not many studies attempt quantification, potential methods include microeconometric or linear programming models.

Public sector. Besides the general public benefits, research has generally ignored the budgetary

consequences that the introduction of standards and regulations may have on public administration bodies, with costs associated with enforcement, monitoring and control. Few attempts have been done in this respect through a direct accountancy approach. Alternatively, these effects could be considered by including the public sector in efficiency studies, e.g. through microeconometric models.

Environment. Food safety regulations, like measures limiting pesticide residues in foods or organic labels, also have environmental consequences through changes in agricultural production and food processing systems. The evaluation of environmental sustainability of food production and consumption has gained relevance in policy making, even though no specific attention has being paid to the estimation of environmental effects of food safety measures. Environmental impacts can be quantified through microeconometric models (e.g. multi-output profit functions, supply analysis) or equilibrium approaches based on linear programming models. Methods specific to quantification (but not monetisation) of environmental effects, like life-cycle impact assessment (see e.g. Margni et al., 2002), may also be exploited to integrate policy evaluation.

Other economic impacts. This residual category includes a variety of impacts which can be classified into 3 main categories: (a) macroeconomic impacts (e.g. effects on economic growth, investments, inflation, etc.); (b) labour market (e.g. job creation and loss, mobility); (c) distributional effects (differentiated impacts across sub-groups of the population, e.g. vulnerable or low-income groups). The methods used depend on the specific impact being assessed, generally econometric methods are exploited, mainly macroeconometric models or micro-macro models for category (a), and equilibrium models and cost of illness approach for category (b). Consequences for job market caused by a regulation in the food system are not directly addressed in the available literature, although some broader equilibrium studies allow for effects on the job market.

3. Quantitative methodologies

We propose a further classification, this time on the quantitative methods for impact assessment, which should allow highlighting the main advantages, limitations and potential extension of each set of techniques. A selection of studies - which we consider as representative with respect to the techniques employed in the literature to evaluate impacts according to our 9-impact classification - is presented in Appendix.

Cost of illness. The cost of illness method (see e.g. EPA, 2007) provides a measure of the distortions to the economy arising from illness and premature death through a quantification of direct medical expenses and indirect costs related to human capital (forgone wages, lost productivity) and is mainly employed to quantify the public health benefits of a risk-reduction policy. The advantages of COI studies are that they are simple, concrete and easily understood. Aggregations and comparisons are relatively straightforward as estimates reflect actual costs of medical services and wages (Roberts and Marks, 1995). However, this method has some drawbacks. Adequate data are not always available for acute illnesses and it is quite difficult to obtain costs of chronic complications from foodborne diseases. Furthermore, the COI estimate is a lower bound of the actual costs borne by society, since pain, lost of leisure time, legal costs for lawsuits, prevention and averting costs are usually not considered (Golan et al., 2000), although some studies try and consider additional economic costs besides those explicitly incorporated in COI (Buzby et al., 1996). Another issue relates to the value of human lives, which is associated to foregone wages. This implies that the value of better paid individuals is higher than those with lower wages, which casts ethical considerations (OECD, 2003). Productivity losses and in-

direct costs are also difficult to be quantified. COI studies have been extensively used in USDA cost-benefit analysis of HACCP introduction for meat and poultry plants in 1996 (Crutchfield et al., 1997; Buzby et al., 1996).

Willingness-to-pay studies. Rather than an evaluation technique, WTP is the objective of a variety of elicitation methods where the final aim is an estimation of the largest monetary amount that an individual would be willing to pay for a specified change in food safety levels or other product attributes. Alternatively, through willingness-to-accept (WTA), the amount of additional income required as a compensation when no intervention is taken (or when the intervention worsens off the respondent situation). Methods of WTP estimation include (EPA, 2000): (a) contingent valuation; (b) conjoint analysis; (c) experimental auctions; (d) hedonic price analysis. The first three methods are direct ways to elicit what consumers would pay for hypothetical foods with a reduced risk of foodborne illness. Hedonic price analysis is an indirect method which relies on observed market price differentials across foods with different safety levels, after accounting for any other product characteristic.
Compared to COI studies, WTP methods are considered as the upper bound estimate of the economic effects on public health, since they account for any indirect welfare impact which is not reflected in health care costs, like pain or time loss. However, there are many concerns about the direct elicitation of these values due to measurement bias, although precautions have been developed in the literature to minimise biases. For example, the hypothetical nature of the survey usually leads to an overestimation by the concerned party (Roberts and Marks, 1995). A strength is the possibility to relate individual WTPs to a set of respondent characteristics (e.g. education, income, etc.) which may allow a better evaluation of impacts across sub-groups of the population (Kuchler and Golan, 1999), although this raises some aggregation issues. Another limitation of direct WTP methods is that they are usually expensive (OECD, 2003) and results are sensitive to the type of question, for example WTP and WTA are unlikely to be equal. Another issue, especially relevant in contingent valuation studies, is the discrepancy between individual risk perceptions and objective risk, with a tendency to inflate small risks compared to higher risks (Lin and Milon, 1995).
Contingent valuation (CV). The most developed and used method to measure WTP is contingent valuation, where the value of the non-market good (e.g. reduction of foodborne illnesses) can be inferred from the amount of income that respondents would be willing to forgo to obtain a specified level of risk reduction, in a hypothetical scenario (Lin and Milon, 1995). Even though contingent valuation is a flexible methodology that can be tailored to analyse specific food safety regulations and is less expensive than market experiments, this method has the above mentioned shortcomings. Respondents often do not have an adequate risk knowledge or cannot distinguish among different risk reduction magnitudes, and they give different valuations depending on the question format, i.e. whether the information format is presented in relative or absolute terms (Buzby et al., 1995; Lin and Milon, 1995).
Conjoint analysis (CA). In conjoint analysis studies, respondents are asked to rate similar products with different combinations of attributes (including price), in order to tease out – generally through discrete choice models – the marginal value of the attributes and their relative importance. Whilst the CV method estimates the total value for a change by asking respondents directly what they would be willing to pay for certain attributes, CA estimates indirectly the marginal value for that change (Halbrendt et al., 1995). Concerns have been raised about the viability of disaggregating the product into several attributes (EPA, 2000)
Experimental auction markets. In conjoint analysis and contingent valuation studies, respondents know they are in a hypothetical scenario. Experimental auction markets (see e.g. Hayes et al., 1995) attempt to overcome this drawback by using real money and real food products. There are several ways to conduct experimental auction markets, the most widely used is the second-

price sealed-bid auction where participants give sealed bids for the product on offer, and the highest bidder buys the product to a price equal the second-highest bid. Experiments can be used either ex ante to improve contingent valuation surveys or ex post as an independent method (Fox et al., 1995).

Hedonic pricing. The hedonic pricing method differs from the other methodologies as it relies on observed price and consumption data to estimate an hedonic function. Thus, it provides a more objective valuation of food attributes (Kim and Chern, 1995). Basically, the hedonic function relates the overall price of food products to their individual characteristics, including some indicator of risk or safety levels. The modelling approach (even a simple regression) allows to evaluate the marginal contribution of each attribute to the overall price. However, food safety is often bundled with other food attributes, like environmentally friendly production practices. Application of such methods, therefore, is mainly found for food attributes like nutrient contents rather than food safety.

Liability costs. An alternative route to quantification of benefits from a food safety regulation is the measure of (potentially) avoidable costs for parties in product liability cases (Caswell, 1998). This approach retrieves the outcomes of jury trials and the compensatory monetary awards to estimate the economic impact of food safety failures, which could be prevented or limited by appropriate regulations (Buzby et al., 2001). A drawback is that these data are not easily accessible, often out-of-court settlements sort out the case before the final judgement.

Direct accountancy methods. These methods measure real-resource compliance costs, i.e. provide a one-time estimate of fixed and variable costs that accrue to industry (direct compliance cost method). No additional modelling is undertaken. This approach estimates compliance costs within a static framework and as such is the simplest kind of cost analysis (OECD, 2003; EPA, 2000). It is used to analyse impacts on firm competition by comparing costs on different size plants (see Crutchfield et al., 1997; Ollinger et al., 2004), the costs that accrue to public bodies (Crutchfield et al., 1997) and the impacts on innovation (see Ollinger et al., 2004). The direct compliance cost method is simple, straightforward and easy to understand. This is probably why it is the most used method to quantify food industry costs in regulatory impact assessments of food safety regulations, for example HACCP rules introduced in 1996 in the US (USDA, 1996). It should be noticed that this method does not take into account other categories of social costs (e.g. social welfare losses), resulting in overestimation of private costs (EPA, 2000).

Partial equilibrium models. A variety of economic effects of regulations (e.g. demand and supply shifts, trade effects, price changes, etc.) can be estimated using a partial equilibrium supply and demand model of the affected market. For example, a new food safety regulation that increases production costs will cause an upward shift in the supply function. The demand function, the old and new supply function, prices, quantities and possibly trade can then be used to assess welfare changes. Partial equilibrium models allow to estimate the changing distribution of social costs over time, but do not account for interactions among two or more markets (EPA, 2000). Between partial equilibrium (one market) and general equilibrium models (the whole economy), one can apply a multi-market version (Unnevehr et al., 1998; Roosen and Hennessy, 2001). Equilibrium models are especially relevant to the analysis of trade impacts (van Tongeren et al., 2001; Roberts et al., 1999).

General equilibrium models. These models extend partial equilibrium analysis to capture interactions between all sectors of the economy. They look at the impacts in both the factor and input markets and allow analysis of different types of impacts on different types of agents (consumers, businesses, distributional impacts, overall trade, etc.). Three types of techniques are

used for the analysis of regulatory impacts: input-output (I-O) models, linear programming (LP) models, and computable general equilibrium (CGE) models. An extensive review of applications to agricultural policy is provided in van Tongeren et al. (2001). Input-output tables record the flow of goods and services through the economy, usually measured as transactions occurring within a single year. Social accounting matrices (SAM, see e.g. Golan et al., 2000) extend input-output analysis to account for institutional incomes and expenditures. In addition, Golan et al. (2000) use SAM to determine the distribution of benefits within the population, and also show the distribution of HACCP-related costs on the economy (e.g. on final consumers in the form of higher prices). The I-O model can be further extended to a LP model (see Onal et al., 2000), where a linear objective function (e.g. profit for producers) is maximised through the allocation of inputs and outputs, subject to budget and technical constraints. The choice of constraints may influence the model solution, which is not necessarily realistic. Furthermore, consumer and producer behaviours are not explicitly accounted for, like in I-O tables. I-O, SAM and LP models can be generalised to CGE models when behaviours of the economic agents are explicitly modelled by using available elasticities or through econometric estimation. An example of a global CGE model for trade analysis is the GTAP model (Hertel, 1999). An application of CGE to the 1992 harmonisation of EU standards (including food standards) is found in Gasiorek et al. (1992).

Microeconometric models. This is a vast class of estimation methodologies, which can be applied to a variety of models for micro-level economic behaviours, mostly consumer demand and producer supply models, but also simple binary or multiple decision models (e.g. Bukenya and Nettles, 2007 on decisions to adopt HACCP). The success of microeconometric models in representing policy impacts largely depends on the data quality and a correct model specification. For example, Antle (2000) estimates a cost function model to explore the impact of product safety on firm efficiency, with an application to the effects of meat safety regulations on variable costs for various meat products, taking also into account different firm sizes (see also Nganje et al., 1999). Teisl et al. (2001) estimate the consumer welfare impact of a labelling measure by exploiting microeconometric estimation of a demand system.

Macroeconometric models. As for microeconometric models, this category may include a wide range of models, applied on aggregate rather than micro-level relationships. A relevant example is the application of gravity models to model changes in international trade balances in response to food safety regulations (see e.g. Otsuki et al., 2001). These models have the advantage of "letting the data speak", as there is no need to predetermine the direction of effects (Anders and Caswell, 2007) and elasticities of trade flows are estimated directly on the data. A drawback is that data (preferably in a panel form) are rarely adequate and the models only returns aggregate evaluations (and may suffer from aggregation biases). Taylor et al. (1991) exploits an econometric-simulation model called GEM ("general economic model") to assess the impact of pesticide reduction regulations on inflation and economic growth. The estimation methods are not necessarily parametric, for example Wu (2004) exploits a non-parametric approach to estimate export sensitivity to regulations for a selection of countries.

Other techniques specific to environmental impact evaluations. This area is extremely broad, given the relevance of environmental impacts for a variety of policies. The focus, obviously, is the quantification (and not necessarily monetisation) of environmental effects of regulations. Quantitative techniques can be based on a direct estimation/accountancy approach (see e.g. Pretty et al., 2000), although more complex impact assessment models exist (for example biological risk models). Among the techniques, one is especially relevant to food regulations, i.e. life-cycle analysis (see e.g. Jones, 2002), which aims at eliciting the environmental impacts at

each stage of the production and consumption process.

4. Important issues for impact estimation

Additional information on the selected studies is given in Appendix, which raises some issues to be considered when performing an impact assessment.

Stage of evaluation. Evaluation can be carried out in a prospective (ex-ante evaluation) as well as a retrospective (ex-post evaluation) perspective, or in a combination of both.
In ex ante assessments, problems arise from various issues. The benefits and costs of a food safety regulation usually accrue not at one point in time, but over a "some-years" time horizon. This issue poses problems of using an appropriate discount rate and time horizon. A sensitivity analysis may be performed by choosing different combinations of assumptions about effectiveness of the regulation, discount rates, valuation methodology, etc. Consequently, there is no single correct estimate of regulatory benefits, because the estimates depend on assumptions made.
In ex post evaluations, impact analysis should involve comparing welfare with and without the regulation. It is very important, but very difficult, to find the right "counterfactual", i.e. the right "without regulation" scenario, that is what would have happened if the regulation was not introduced. For methodologies that require survey data, problems of selection bias can arise, when people choose either to or to not participate for specific reasons, or selection process of individuals to be surveyed is not random but follows specific criteria.
Another issue we want to highlight is the need for consistency between ex ante and ex post evaluations. RIA Guidelines (2005) of the EC encourage analysts carrying out a RIA to outline the monitoring and evaluation arrangements in the proposal. In most RIAs performed by EU countries such indications are reported in a piecemeal fashion. It seems there is not a link between an ex ante and its relative in itinere monitoring and ex post evaluation.

Level of assessment. Analyses at the micro level refer to economic quantitative evaluations based on individual economic agents (e.g. consumers, industries, importers, etc.), even if they are aggregated at a later stage (e.g. evaluating the impact using individual consumer data, then obtaining the overall impact by averaging / summing the individual impacts on a territorial or sectoral basis).
Analyses at the macro level refer to economic quantitative evaluations based on data that are already aggregated (e.g. time series of territorial data, or consumption data for a whole country) and rely on models that do not take into account individual behaviour, but explore the relationships among the aggregate outcomes.
Policy-makers are interested in aggregate outcomes as well as distributional impacts, which raises the need for models which can be applied both at the micro and macro level.

Type of data. The use of a method instead of another can entail the use of different types of data. Each type of data presents limitations. Cross-section data do not take into account the dynamics of the regulatory impact. Time-series data are not heterogenous. Panel data overcome the shortcomings of the former two types, but are not easily available.

Geographical scope of evaluation. We indicated whether the analysis was conducted at international, national, regional or local level, and the countries involved.
The majority of the studies are at national level, mainly in the USA. This confirms the fact that impact evaluation is relatively new in EU compared to the US, and consequently we found no academic studies on EU countries, except for a few ones on the UK. The studies on international

trade effects usually focus on interaction between either USA and developing countries or EU and developing countries.

5. Final considerations

We have provided a classification of quantitative methodologies emerging from a selection of studies that aim at evaluating impacts of food safety regulations. This review is far from being exhaustive with respect to the actual and potential methodologies applicable in impact assessment of food safety regulations. Notwithstanding, beyond the weaknesses of each methodology, there are some general issues, emerged in the last section, which deserve special attention when performing an impact evaluation.

First of all, food safety is a non-monetary attribute of food products, and as such is difficult to quantitatively measure it or assign a value to it. It is also difficult to assign a monetary value to a variety of consequences arising from food safety, especially benefits (value to life, access to new markets, retention of customers, improvements in shelf life, etc.). In addition, even for well-designed techniques, the obstacle for an effective application is the lack of adequate data, not easily accessible for various reasons. Another key point is the difficulty for methods to capture the dynamic aspect of an impact. This has important policy implications, arising from the fact that, for example, industries might be reluctant to adopt a regulation that requires them to pay some costs, if they are not aware of the private and public benefits that are supposed to accrue at a later stage after the implementation of a regulation. In that respect, econometric models enabling an analysis of impact patterns are preferable. Furthermore, policy-makers are interested in aggregate outcomes as well as distributional impacts, which raises the need for models encompassing both the micro and macro level. Finally, the relationship among ex ante, in itinere and ex post evaluation is not clear, worsened by the lack of consistency between methods used in different evaluation stages.

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Appendix - Selected literature on quantitative methods for evaluating food safety regulations

Reference	Object of evaluation	Method	Stage	Level	Data	Geograhical Scope
Public health and security						
Roberts and Marks, 1995	Medical costs and productivity losses caused by acute and chronic illness caused by selected microbial foodborne diseases (emphasis on E.coli)	Cost of illness	ex ante	macro	cross-section	national USA
Buzby et al., 1996	Medical and lost productivity costs from six bacterial foodborne diseaes (support for HACCP regulation)	Cost of illness	ex ante	macro	cross-section	national USA
Crutchfield et al., 1997	Monetization of the annualized net benefits of reductions in foodborne illnesses from HACCP introduction in poultry and meat sector	Cost of illness	ex ante	macro	cross-section	national USA
Buzby et al., 1995	Consumers' WTP for reduced food safety risk through banning a specific postharvest pesticide from use in fresh grapefruit packinghouse	Contingent valuation (WTP)	ex ante	micro	cross-section	national USA
Lin and Milon, 1995	Consumers' WTP for reduced health risks from eating oysters (hypothetical scenario of an inspection program)	Contingent valuation (WTP)	ex ante	micro	cross-section	regional USA
Fox et al., 1995	Consumers' WTP for reduced risk of illness from Salmonella in meat following improved screening procedures	Experimental auction (WTP)	-	micro	cross-section	regional USA
Hayes et al., 1995	Consumers' option price for a reduction in risk and compensation measures for an increase in risk from five foodborne pathogens (different screening levels)	Experimental auction (WTP)	ex ante	micro	cross-section	local USA
Consumers and households						
Halbrendt et al., 1995	Impact of nutrition information on consumers' attitudes (toward genetic engineering to manufacture pST), consumer trust towards food-safety related organizations, consumer preferences for pork produced with and without pST	Conjoint analysis (WTP)	ex ante	micro	cross-section	national Australia
Kim and Chern, 1995	Monetization of consumer values of various fatty acids contained in major fats and oils and impact of consumer health info on demand for fats and oils	Hedonic pricing, microeconometric demand model	ex post	micro	panel	national USA
Roosen and Hennessy, 2001	Demand shifts in two hypothetical bans on organophosphate insecticides in apple production	Partial equilibrium (multi-product approach)	ex ante	macro	panel	national USA
Teisl et al., 2001	Impact on consumer choice of an experimental nutrition labeling program	Microeconometric demand model	ex post	micro	panel	regional USA
Third countries and international relations						
Anders and Caswell, 2007	Impact of HACCP on seafood imports to the U.S. by the 35 largest seafood exporting countries	Macroeconometric (gravity model)	ex post	macro	panel	international USA
Otsuki et al., 2001	Impact on food exports for nine African exporters of proposal of harmonised aflatoxin standards in EU countries	Macroeconometric (gravity model)	ex ante	macro	panel	international EU Africa
Wu, 2004	Export loss for a food crop, given an hypothetical internationally imposed mycotoxin standard for major food crop exporting countries	Macroeconometric + sensitivity analysis	ex ante	macro	cross-section	international USA China Argentina Africa
Firm competition						
Crutchfield et al., 1997	Comparison of HACCP rule costs for different size slaughter plants	Direct accountancy	ex ante	macro	panel	national USA
Ollinger et al., 2004	Differential effects of HACCP by (a)plant size and (b) meat type	Direct accountancy	ex post	micro	cross-section	national USA
Antle, 2000	Costs of HACCP in meat industry by size plant	Microeconometric (quality-adjusted cost function models)	ex ante	micro	panel	national USA
Nganje et al., 1999	Impact of HACCP on output price for small meat processors and packers	Microeconometric (profit function)	in itinere	micro	panel	national USA
Golan et al., 2000	Difference in economic costs and benefits among different sectors of the economy following the introduction of HACCP in poultry and meat sector	General equilibrium (SAM)	ex post	macro	panel	national USA
Onal et al., 2000	Differential impact according to industry size and region of the costs of reducing Salmonella contamination in pork following the 1996 introduction of HACCP	Linear programmino model	ex ante	micro	panel	national USA
Unnevehr et al., 1998	simulate the effects of increased costs on producer welfare in beef, pork and poultry industries from HACCP	Partial equilibrium (multi-market model)	ex ante	macro	panel	national USA

Conduct of businesses						
Buzby et al., 2001	Incentives that product liability law provides firms to produce safer food	Liability costs	-	micro	panel	national USA
Crutchfield et al., 1997	Estimate (20-year annualized) costs of HACCP in poultry and meat inspection	Direct accountancy	ex ante	macro	panel	national USA
Ollinger et al., 2004	Fixed and variable costs for compliance under HACCP (meat and poultry)	Direct accountancy	ex post	micro	cross-section	national USA
Boland et al., 2001	Postimplementation cost estimates for HACCP in small meat plants	Direct accountancy	ex post	micro	cross-section	regional USA
Roosen and Hennessy, 2001	Estimate marginal cost changes in two hypothetical bans on organophosphate insecticides in apple production	Partial equilibrium (multi-product approach)	ex ante	micro	panel	national USA
Onal et al., 2000	Impact on costs and efficiency of reducing Salmonella contamination in pork	Linear programming model	ex ante	micro	panel	national USA
Antle, 2000	Impacts of HACCP on variable cost of production in meat industry	Microeconometric (quality-adjusted cost function model)	ex ante	micro	panel	national USA
Bukenya and Nettles, 2007	Examines whether goat producers are willing to voluntarily adopt HACCP	Microeconometric (binary logit regression equation)	ex ante	micro	cross-section	regional USA
Innovation and research						
Ollinger et al., 2004	Changes in food safety technology and practices of industries after HACCP adoption	Direct accountancy (compliance costs + technology index)	ex post	micro	cross-section	national USA
Public sector						
Crutchfield et al., 1997	Estimate costs accruing to federal government for implementation of HACCP	Direct accountancy + estimates	ex ante	macro	panel	national USA
Environment						
Pretty et al., 2000	Costs of externalities induced by agriculture in UK (e.g. pollution)	Direct accountancy + estimates	ex post	micro macro	panel	national UK
Jones, 2002	Environmental impacts of transport components of alternative food supply chains (predominant fresh produce and localized systems) (dessert apple)	Life-cycle analysis	-	micro	cross-section	local UK
Other effects on the economy						
Golan et al., 2000	Distributional impact of HACCP, considering costs and benefits of reduction in foodborne illness across household types and industry sectors	General equilibrium (SAM)	ex post	macro	panel	national USA
Taylor et al., 1991	Effects of chemical use reductions on macroeconomic variables (GNP, inflation, government budget, interest and exchange rates, etc.)	Macroeconometric (GEM)	ex ante	macro	cross-section	regional USA