Measuring the Impacts of Food Safety Regulations: A Methodological Review

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Abstract— **Together with a call for more effective and efficient regulations in the EU, there is a growing demand for transparency in the evaluation methods used to assess their effects. This paper proposes a classification of the impacts that food safety regulations can produce and discusses the quantitative methods that are used in the literature to measure those impacts. Along with the strengths and limitations of each methodological approach, this review highlights other transversal issues relevant when developing assessment strategies, like the unbalance between ex-ante and ex-post evaluation, the lack of adequate data, the difficulty of estimating the dynamic effects of regulations, and the possibility of endogenous relationships.**

Keywords— **impact assessment, food safety regulation, quantitative methods**

I. Introduction

The European Commission and national governments increasingly require ex-ante impact assessment prior to the adoption of regulatory proposals and policy interventions in the food safety area. The call for sound evaluation strategies is relatively new compared to the US experience and to other policy areas, especially environmental measures, energy and transport. Together with a call for evidence-based policies, there is an increasing demand for clarity on the techniques employed for the quantification of individual policy effects. This is especially relevant in policy areas where a multitude of methods has been proposed, not rarely with conflicting results, as it is the case for food safety regulations. While an ongoing debate exists on the general evaluation framework (e.g. cost-benefit analysis, regulatory impact assessment, risk-risk analysis, etc.), our focus here is on the founding elements of any quantitative assessment exercise, the statistical techniques for the elicitation of monetary values and the economic quantification of non-market impacts.

Food safety regulations are particularly interesting because of the variety of impacts on different economic actors along the food chain. Furthermore, food safety norms are relevant to a variety of policy areas, like health and consumer protection, competition, trade and environment.

With the aim of providing an overview of the state of the art, this paper is structured as follows. First, a classification of potential impacts is proposed, as they emerge from a variety of official documents like the European Commission impact assessment guidelines (EC-IAG) [1]. Then, drawing from the existing literature, the impacts were associated with the range of quantitative methods which allow measurement and estimation. Finally, considering the strengths and weaknesses of these methodologies, a discussion of their contribution to solve emerging evaluation issues is set up.

II. A classification of impacts

Current impact assessment at the EU level is mainly based on the EC-IAG, developed in response to the call for "better regulations" [2], which requires instruments to support the adoption of more effective and efficient regulations, as well as an improved co-ordination of policy interventions across the economic, social and environmental dimensions. The EC-IAG [1, p. 29-32] identify a list of 32 potential impacts of a regulation, independently from the policy area. Here a simplified classification based on the above is proposed, which is considered as complete with respect to the impacts of food safety regulations and allows a better correspondence with the quantitative methodologies found in the literature.

This simplified and aggregate list includes 9 potential impacts of a food safety regulation. These impacts are reviewed in relation with the quantitative techniques commonly employed for evaluation.

Public health and security. Food safety regulations have the primary objectives of safeguarding public health and reduce the risk of illnesses and the associated health costs. 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 the public health benefits as a component of the overall evaluation exercise.

Consumer and households. Regulations have an impact on households and consumers beyond the public health effects. 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-parameteric 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 level. 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. 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, as discussed later in this paper.

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 effects that the introduction of standards and regulations may have on public administration bodies, with costs associated with enforcement, monitoring and control which ultimately fall on the taxpayer. 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 the quantification (but not monetisation) of environmental effects, like life cycle impact assessment [see e.g. 3] 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 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 to analyse distributional effects. 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.

III. QUANTITATIVE METHODOLOGIES FOR IMPACT EVALUATION

A further classification is proposed, this time on the quantitative methods for impact assessment, which should allow to highlight the main advantages, limitations and potential extension of each set of techniques. A selection of empirical applications of evaluation techniques found in the literature and classified according to our 9-impact classification is presented in the table in Appendix.

Cost of illness. The cost of illness method [see e.g. 3] 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 comparison are relatively straightforward as estimates reflect actual costs of medical services and wages [5]. 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 [6], although some studies try to consider additional economic costs besides those explicitly incorporated in COI [7]. 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 [8]. Productivity losses and indirect 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 [7, 9].

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[1]. Methods of WTP estimation include [10]: (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 [5]. 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 [11], although this raises some aggregation issues. Another limitation of direct WTP methods is that they are usually expensive [8] and results are sensitive to the type of question. 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 [12].

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 [12]. 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 [12, 13].

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 [14]. Concerns have been raised about the viability of disaggregating the product into several attributes [10].

Experimental auction markets. In conjoint analysis and contingent valuation studies, respondents know they are in a hypothetical scenario. Experimental auction markets [see e.g. 15] attempt to overcome this shortcoming 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

1. [1] To avoid potential confusion in the classification due to the potential use of WTP methods to assess both public health and consumer impacts, our choice was to discriminate studies according to the object evaluation. When the assessment focuses explicitly on health risks, articles are classified under "public health impact", when the assessment is targeted at effects on consumer choice (e.g. taste, availability of new products, changes in nutrient contents, other product characteristics unrelated to safety), then the classification was under "consumer and household impact".

bid. Experiments can be used either ex ante to improve contingent valuation surveys or ex post as an independent method [16].

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 [17]. 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 [18]. 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 [19]. A drawback is that these data are not easily accessible, because out-of-court settlements often 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 [8, 10]. It is used to analyse impacts on firm competition by comparing costs on different size plants [see 9, 20], the costs that accrue to public bodies [9] and the impacts on innovation [see 20]. 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 [21]. 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 [10].

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 [10]. Between partial equilibrium (one market) and general equilibrium models (the whole economy), a multi-market version can be applied [22, 23]. Equilibrium models are especially relevant to the analysis of trade impacts [24, 25].

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. [24]. 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 [6]) extend input-output analysis to account for institutional incomes and expenditures. In addition, Golan et al. [6] use SAM to determine the distribution of benefits within the population and also shows 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 [26], 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 [27]. An application of CGE to the 1992 harmonisation of EU standards (including food standards) is found in Gasiorek et al. [28].

*Microeconometric model*s. 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 [29] 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 [30] 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, and takes also into account different firm sizes (see also Nganje et al. [31]). Teisl et al. [32] 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. [33]). These models have the advantage of "letting the data speak", as there is no need to predetermine the direction of effects [34] 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. [35] exploit 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 [36] employs a non-parametric approach to estimate export sensitivity to regulations for a selection of countries.

Event study analysis. This methodology exploits time series econometrics to evaluate the impact of regulations when historical observations are available before and after the introduction of a policy measure. A typical application is the evaluation of financial markets response to new regulations [37] or to recalls due to food safety incidents [38]. Given the large availability of financial data, this approach has the advantage of allowing a timely application. However, the evaluation is short-term and limited to financial effects which are not necessarily reflected by markets in the longer term.

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. 39], although more complex impact assessment models exist (for example biological risk models). Among the techniques, one is especially relevant to food regulations, life-cycle analysis [see e.g. 40], which aims to elicit the environmental impacts at each stage of the production and consumption process.

IV. Conclusions

The table in Appendix shows a non-comprehensive but representative selection of studies targeting an economic quantification of the impact of food safety regulatory measures. This selection aims at providing a picture of the existing range of modelling and assessment techniques, which can provide support information for broader evaluation frameworks like regulatory impact assessment, cost-benefit analysis or multi-criteria methods [41]. While we have highlighted some of the strengths and limitations of the methodological approaches, many other issues deserve further consideration when developing an assessment strategy. For example, there is a major unbalance between ex-ante, in itinere and ex-post evaluation, usually worsened by a lack of consistency between the techniques employed in different stages of the evaluation process. Furthermore, the applicability of the methods discussed here is often hindered by the lack of adequate data, especially panel data which could allow a simultaneous assessment of time-dependent effects and heterogeneity in the impacts. Dynamic effects are currently under-investigated, but they may be the key barrier to the implementation of successful policies, especially discounting effects that often discourage firms from adopting measures whose benefits accrue much later than the costs, sometimes with uncertainty. In that respects, some of the econometric and micro-simulation methods which enable an analysis of the impact patterns are preferable. Another aspect which should not be ignored when selecting the quantification method is the potential existence of feedback loops or endogenous relationships. Finally, 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. The statistical toolbox for the evaluation of food safety regulations is far from being exhaustive compared to the growing needs of evidence-based policymaking, especially considering the trade-offs between accuracy and simplicity.

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

Reference	Object of evaluation	Method
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)	COI
Buzby et al., 1996	Medical and lost productivity costs from six bacterial foodborne diseaes (support for HACCP regulation)	COI
Crutchfield et al., 1997	Monetization of the annualized net benefits of reductions in foodborne illnesses from HACCP introduction in poultry and meat sector	COI
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)
Lin and Milon, 1995	Consumers' WTP for reduced health risks from eating oysters (hypothetical scenario of an inspection program)	Contingent valuation (WTP)
Fox et al., 1995	Consumers' WTP for reduced risk of illness from Salmonella in meat following improved screening procedures	Experimental auction (WTP)
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)
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)
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
Roosen and Hennessy, 2001	Demand shifts in two hypothetical bans on organophosphate insecticides in apple production	Partial equilibrium (multi-product approach)
Teisl et al., 2001	Impact on consumer choice of an experimental nutrition labeling program	Microeconometric demand model
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)
Otsuki et al., 2001	Impact on food exports for nine African exporters of proposal of harmonised aflatoxin standards in EU countries	Macroeconometric (gravity model)
Wu, 2004	Export loss for a food crop, given an hypothetical internationally imposed mycotoxin standard for major food crop exporting countries	Macroeconometric + sensitivity analysis
Firm competition		
Crutchfield et al., 1997	Comparison of HACCP rule costs for different size slaughter plants	Direct accountancy
Ollinger et al., 2004	Differential effects of HACCP by (a)plant size and (b) meat type	Direct accountancy
Antle, 2000	Costs of HACCP in meat industry by size plant	Microeconometric (quality-adjusted cost function models)
Nganje et al., 1999	Impact of HACCP on output price for small meat processors and packers	Microeconometric (profit function)
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)
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
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)
Conduct of businesses		
Buzby et al., 2001	Incentives that product liability law provides firms to produce safer food	Liability costs
Crutchfield et al., 1997	Estimate (20-year annualized) costs of HACCP in poultry and meat inspection	Direct accountancy
Ollinger et al., 2004	Fixed and variable costs for compliance under HACCP (meat and poultry)	Direct accountancy
Boland et al., 2001	Postimplementation cost estimates for HACCP in small meat plants	Direct accountancy
Roosen and Hennessy, 2001	Estimate marginal cost changes in two hypothetical bans on organophosphate insecticides in apple production	Partial equilibrium (multi-product approach)
Onal et al., 2000	Impact on costs and efficiency of reducing Salmonella contamination in pork	Linear programming model
Antle, 2000	Impacts of HACCP on variable cost of production in meat industry	Microeconometric (quality-adjusted cost function model)
Bukenya and Nettles, 2007	Examines whether goat producers are willing to voluntarily adopt HACCP	Microeconometric (binary logit regression equation)
Salin and Hooker, 2001	Stock exchange impact of recalls due to microbiological food contamination	Event study
Johnson et al., 1992	Financial impact of a variety of regulations on listed meat-packing companies	Event study
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)
Public sector		
Crutchfield et al., 1997	Estimate costs accruing to federal government for implementation of HACCP	Direct accountancy
Environment		
Pretty et al., 2000	Costs of externalities induced by agriculture in UK (e.g. pollution)	Direct accountancy
Jones, 2002	Environmental impacts of transport components of alternative food supply chains (predominant fresh produce and localized systems) (dessert apple)	Life-cycle analysis
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)
Taylor et al., 1991	Effects of chemical use reductions on macroeconomic variables (GNP, inflation, government budget, interest and exchange rates, etc.)	Macroeconometric