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# COMPARATIVE ANALYSIS OF COST-EFFECTIVENESS OF CO-REGULATORY APPROACHES TO FOOD SAFETY CONTROLS

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**Abstract**

Food safety controls are currently enforced in the UK by a variety of regulatory approaches that considerably differ in their efficiency and effectiveness in achieving social goals of safe food supply and improved consumer confidence. Aim of this study is to establish whether a co-regulatory enforcement of these controls is more cost-effective than the traditional command-and-control enforcement modes.

First of its kind, the study reviewed a vast theoretical literature on economics of food safety and incentives to develop a conceptual framework and appropriate methodology for comparative cost-effectiveness analysis of co-regulatory approaches to food hygiene controls in the UK meat industry. A panel data on costs and compliance of 710 meat firms operating in the UK and Northern Ireland is collected analysed using fixed-effects model.

Results of this analysis show that the co-regulatory approaches can be cost-effective when regulators are capable of devising incentive mechanism that encourages compliance. These findings call for a systematic evaluation of existing regulatory and market incentives to facilitate a more widespread consideration of co-regulation in the UK food industry and supply chains, particularly in sectors that do not presently lend themselves to co-regulation.

The findings of the study have empirical implications for food policymakers, analysts and enforcement officers engaged in the analysis, development and implementation of strategies for improving food safety.

## 1. Introduction

The protection of public health and the role of consumers in the development of regulation of food safety[1] have recently risen to the top of the political agenda of the European Commission (EU) following a series food scares that resulted in a sharp fall of consumer confidence in the EU food safety governance systems and industry practices in 1990s (see Cantley 2004; Caduff and Barnaeuer 2006; Halkier 2006). Among these incidents were dioxins in chicken feed in Belgium and outbreak of Bovine Spongiform Encephalopathy (BSE) and its transmission to humans in the form of the new variant Creutzfeldt-Jakob disease in the UK (Ansell and Vogel 2006).

The resulted public mistrust of the food safety governance systems has hampered the credibility of the regulators to the extent that it challenged the legitimacy of the institutional status quo both at EU (Chalmers 2003) and member states levels (Borraz, Besancon et al. 2006; Rothstein 2006). In response to the political pressure from a growing public demand for more effective controls, the EU Commission have subsequently introduced a White Paper on Food Safety (European Commission 2000a). The White Paper have triggered important regulatory reforms, including a new legislation establishing the European Food Safety Authority (EFSA) and making explicitly ensuring food safety the primary legal responsibility of food business operators (European Commission 2002).

The food industry, on its part, responded to the consumers' demand for effective food safety controls with the development technologically sophisticated and organisationally complex range of approaches to improving product safety and quality standards (Henson and Georgina 2000; Henson and Hooker 2001; Fearne and Garcia Martinez 2005; Henson and Reardon 2005). Examples of these new private governance systems include EUROPGAP/GLOBALGAP and British Retail Consortium's standard, which although set on voluntary basis are increasingly

[1] Safe food means "food that is wholesome, and that does not exceed an acceptable level of risk associated with pathogenic organisms or chemical and physical hazards" as defined by the Institute of Medicine and National Research Council (1998). Ensuring food safety: from production to consumption, National Academy press.

becoming a driving force of food safety governance systems in agribusiness supply chains (Garcia Martinez, Fearne et al. 2007; British Retail Consortium 2008; Humphrey 2008).

In recent times, there also has been a growing interface between public and private sectors in regulating food safety thanks to a shift from traditional command-and-control regulation by government towards alternative more flexible forms of regulation, such co-regulation systems of governance (Bardach and Kagan 1982; Ayres and Braithwaite 1992; Ogus 1994; Garcia Martinez, Fearne et al. 2007). Particularly, there is an increasing tendency to regulate food safety through management-based approaches that direct firms towards internal planning processes that aim at achieving social goal of safe food without unduly restricting their ability to cost-effectively design own food safety assurance systems (Coglianese and Lazer 2003; Balleisen 2009; Ollinger and Moore 2009). Current EU legal framework provides a scope for use of such regulatory approaches. For example, Regulation 178/2002 which lays down the general principles and requirements of food law recognises that food business operators (FBOs) are best placed to devise effective controls to ensure the safety of foods they supply.

In this new setting, whereby the traditional public regulators' responsibilities for food safety controls are increasingly being devolved to industry operators using enhanced private governance systems, calls for evaluation of efficiency of different regulatory approaches used to deliver controls across the food sectors. Particularly, the co-regulation, which combines the binding legislative requirements with a flexible industry self-regulation, is emerging as a promising approach to achieving cost-effectively the social goals of safe food supply and improved consumer confidence (Fearne and Martinez 2005; Martinez, Fearne et al. 2007).

Although a number of UK food sectors, including eggs and poultry meat sectors are currently being governed by regulatory modes that can be classed as co-regulation, nevertheless no comparative analysis is done yet to evaluate the social costs and benefits achieved under these regulatory modes.  This study attempts to the gap in research in this field by evaluating comparatively existing regulatory approaches to enforcement of the official controls of EU food hygiene in the GB poultry sector.

## 2. Theoretical literature

The theoretical literature on economics of food safety suggests that there is a clear allocative rationale for government controls to protect public health on grounds of market failure resulting from asymmetry of information about safety attributes of meat products that may exist between producers/sellers and buyers (Henson and Traill 1993; Antle 1995; Weiss 1995; Unnevehr 2000). This literature identifies three primary reasons as to why the market mechanism may fail to guarantee hygienic production of meat. These include 1) imperceptible nature of most foodborne risks which are not easily detectable before or even after consumption (Caswell and Henson 1997); 2) asymmetries in the information about such risks which entails considerable uncertainties both in consumers' purchasing choice and their demand for regulatory protections (Unnevehr and Jensen 2005); and finally 3) the public good nature of food safety provision often characterised by diverging private and social costs and benefits (Antle 1999).

However, a market failure *per se* does not justify government intervention nor such intervention necessarily improve upon the regulated markets in terms of costs incurred and public health benefits achieved (Antle 1999). This particularly the case as the failure in markets for food safety is never complete and there are always residual incentives for producers to ensure food safety even in the absence of governmental interventions (Unnevehr and Jensen 2005). These residual market incentives include legal liability and reputational concerns of the producers, as well as firm's desire to maintain and/or expand its market share and profit (Caswell 2005).

Therefore, there is a scope for regulatory mechanisms that enhance these incentives to cost-effectively improve food safety (Martinez, Fearne et al. 2007). Particularly, governments need to strike a balance between costs and benefits in choosing a certain intervention approach to improve food safety (Antle 1999; Velthius, Unnevehr et al. 2003). In relation to this, there is a continuum of government interventions ranging from doing nothing, direct command-and-control (CAC); self-regulation; enforced self-regulation; management-based regulation, co-regulation; incentive-based interventions to information-based interventions that provide incentives for private market solutions (Unnevehr and Jensen 2005; Fearne, Garcia Martinez et al. 2006; Moss and Cisternino 2009).

Most of the traditional risk regulation falls into CAC interventions which are coercive modes of which the failure to comply may lead to the imposition of penal sanctions underpinned by criminal law, if only at a last resort (Ogus 1994). These sanctions may be inherent in the form (a person who contravenes a statutory standard commits a punishable offence) or ancillary to it (for certain activities a license must be obtained and engaging in the activity without a licence is punishable offence). Unnevehr and Jenson (2005) identify three types of direct CAC interventions including, performance standards; processing standards and mandatory disclosure of information.

The performance standards typically set statutory limits for microbial count and pesticide residue for a product at some stage of the marketing channel, which have to be monitored by sampling and inspection. Processing standards prescribe procedures, such hygiene operating procedures, to be followed in production to achieve improved final product. Mandatory disclosure of information includes requirements for producers to provide information on any food safety process they use, such ionising irradiation. In practice, traditional food safety regulation may combine various CAC elements to ensure food safety. For instance, under the current hygiene regime for meat hygiene, meat industry operators 1) not permitted to process any cattle over 48 months of age unless tested negative for BSE (i.e. processing standard); 2) are required to remove some legally specified risk materials including spinal cord and offal from carcass (i.e. performance standard) and 3) are required providing (i.e. disclose) a documentary evidence of traceability records all processed animals (Tierney 2007; Food Standards Agency 2008). Therefore, this regime can be classed as a CAC approach.

In contrast, the current UK enforcement model for the delivery of official controls of meat hygiene in the poultry sector closely resamples a co-regulation. Under the current EU regulations, suitably qualified poultry plant's staff members, known as Plant Inspection Assistants (PIAs), can assist public delivery of official controls of meat hygiene by carrying out substantial official auxiliaries tasks under the supervision of an official veterinarian (Food Standards agency 2007c). This delivery model is optional and the auxiliary tasks concerned are usually performed publicly-employed meat hygiene inspectors for firm opting out of the scheme.

The official auxiliary tasks by the PIAs include auditing activities to collect information regarding good hygienic practices and HACCP-based procedures of the production plant; ante-mortem inspection and checks concerning the welfare of animals to conduct initial ante mortem check of animals and post-mortem inspections of carcasses (European Commission 2004). Thus, the regulation provides a legal basis for delegating public responsibilities for enforcement of the official controls potentially leading to savings of considerable regulatory resources that can be deployed elsewhere.

The co-regulatory enforcement approach used for this sector falls within what is known in the literature on regulatory economics as management-based co-regulation (Coglianese and Lazer 2003; Bennear 2007; Balleisen and Eisner 2009). The management-based regulation intervene at the planning stages of production processes to compel firms to a preventive course of actions that improve their internal management systems, so as to achieve efficiently the public goal of safe food supply through private means – i.e. enhanced food safety assurance systems of the firm (Coglianese and Lazer 2003). In effect, under management-based strategies, firms are legally committed to produce plans that comply with general regulatory criteria designed to promote a targeted social goal, for example implementation of HACCP[2], without unduly restricting firm's ability to design cost-effectively own food safety management systems that meet pre-specified regulatory requirements. In addition to the potential efficiency gains from flexible design of internal systems, such approach would also encourage innovation, creating further incentives for voluntary compliance (Unnevehr and Jensen 2005), as well as reducing the regulator's enforcement costs. Thus, co-regulation of meat hygiene controls is potentially more cost-effective than the CAC approach for red meat controls which embody a lack of such flexibility (Martinez, Fearne et al. 2007; Balleisen and Eisner 2009).

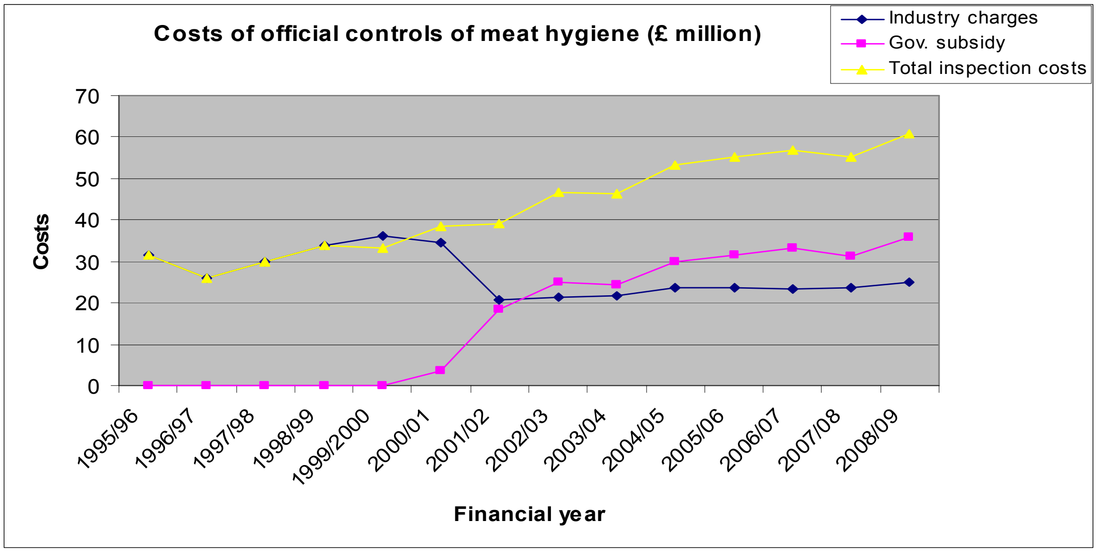
[2] HACCP is acronym of Hazard Analysis Critical Control Points. It is a food safety management system consisting of 7 steps for hazard identification, elimination or reduction to acceptable levels, establishing control limits, verification and monitoring procedures.

## 3. Incentives under co-regulation

However, such delegation of official controls at firm-level may potentially entail incentive incompatibility problems due to the information asymmetry about food safety outcomes of, for example, the partially delegated auxiliary tasks by PIAs with unobservable effort. In effect, it is costly for the regulator to monitor and verify all actions taken by firm's inspectors and food safety outcomes of such actions without incurring considerable costs (Laffont and Tirole 1993; Laffont and Martimort 2002). This information problem have implications for efficiency of the poultry enforcement model, particularly as the regulator is in this case providing financial incentives to the poultry firm to compensate for costs incurred in carrying out the delegated official tasks (Laffont and Tirole 1993). Under the current inspection regime administered by the Meat Hygiene Service[3] (MHS), which is an executive agency of the FSA, the poultry meat firms receive substantial cost reimbursements for official auxiliary tasks carried out by own plant inspectors (MHS 2008). In relation to this, the FSA has allocated the MHS a net subsidy budget of around £36 million in 2009 to, among other things, fund these reimbursement costs (Food Standards Agency 2008). Chart 1 shows the increasing the public and industry cost burdens of these controls which reached over £60 million in 2009. While the proportions of costs recovered from industry remained relative unchanged in recent years, the subsidy costs to the delivery of the official controls, which is borne by the taxpayers, continues to rise. This subsidy reached a record figure of over £35.8 million in 2009.

[3] In Northern Ireland, the official controls of meat hygiene are delivered by Department of Agriculture and Rural Development (DARD)

Chart 1




Source: MHS annual accounts and reports

With regard to the compensation for auxiliary tasks, the regulated firm can potentially exploit information that it privately holds about its production activities and processes to extract economic rents from the regulator by, for example, over claiming costs incurred for producing a certain level of food safety outcome with the knowledge that the regulator cannot verify these activities without incurring substantial monitoring costs (Laffont and Tirole 1993; Laffont and Martimort 2002). Consequently, it is reasonable to expect that, without an effective industry governance system that can fill the gap left behind by the withdrawal of official inspection in delegating official tasks and/or the regulator crafting an effective incentive mechanism that aligns the social goal of safe meat supply with the firm's objective to minimise its production costs, such co-regulatory approach is unlikely be optimal. Private governance systems that can mitigate such incentive problems, include, for example, the above-mentioned industry private governance systems which are often enhanced by an independent third party accreditations and monitoring (Martinez, Fearne et al. 2007; Henson 2008). Thus, the potential efficiency gains from co-regulation of meat hygiene controls may be limited by delegation of official to meat firms operating under weaker industry governance systems and/or effective regulatory mechanism that incorporate negative incentives such as withdrawal of flexible self-controls, escalating inspections/penalties and disclosure of compliance performance of persistent offenders.

Despite these incentive problems in delegation of official controls, there are no published studies in this area to ascertain how information asymmetry affects the cost-effectiveness of the delivery models used. Particularly, two overarching empirical questions yet to answered are 1) whether the co-regulatory delivery of official control is more cost-effective than the command-and-control modes? And 2) what changes need to be made to the existing regulatory and industry incentive structures to facilitate a more widespread use of co-regulation should the approach is found be relatively more cost-effectively. The aim of this study is to address these questions by comparatively evaluating the costs and benefits achieved by co-regulation, taking into consideration the heterogeneity of the firms concerned. For this purpose, a research methodology is developed in the next section.

## 4. Methodology

As mentioned above, the comparative analysis of cost-effectiveness of different food hygiene delivery methods in place requires measuring the costs and benefits of these approaches. In this case, the primary costs of official controls are the cost of compliance, borne by both industry and the regulatory administrative costs borne by taxpayers (Antle 1999). Similarly, the primary benefits of official controls of meat hygiene are reductions in risks of morbidity and mortality associated with meat consumption (namely microbial pathogens) and resulting higher consumer confidence (Unnevehr and Jensen 2005). However, the scope of the study is focus on narrower costs and benefits of co-regulation by examining directly measurably set of administrative costs incurred to achieve a certain level of food safety through improved compliance.

We adopt an econometric approach to evaluate the cost-effectiveness of the co-regulatory enforcement method for the poultry sector against the CAC method used for red meat controls. Such comparative analysis is particularly useful when 1) benefits (in this case reduced meat-bone disease) cannot be measured in monetary terms and 2) the benefits are similar across the enforcement methods in comparison (Boardman, Greenberg et al. 1996; Stiglitz 2000). This is particularly true for this study as, on the one hand, monetising health benefits of the hygiene controls is a difficult tasks due to intangibility of most health benefits from difficulties in allocating a value to the benefits of the controls (Antle 1999; Unnevehr and Jensen 2005; Irz

2008) and linking disease to meat and a firm or industry (Batz, Doyle et al. 2004; Tauxe 2005). On the other hand, we are fittingly comparing two enforcement methods which are primarily concerned with controlling similar microbial foodborne pathogens, with exception to the BSE which is recently lesser an issue (Tierney 2007; Food Standards Agency 2008i).

To overcome these problems, we use firm's compliance as a proxy to public health benefits of official controls understudy, whilst we focus our attention on a set of public subsidy cost to the official controls as the most important administrative costs. Specifically, we calculate incremental subsidy costs and compliance scores (explained next section) achieved by the two distinct enforcement or delivery approaches in question over a specified period. To compare the two enforcement methods, we calculate a cost-effectiveness ratio of the incremental subsidy costs to the incremental compliance scores, so that we can rank the methods based on these ratios.

## 5. Model

For each delivery model, we specify a pair of panel models – one equation for the costs and a second equation for firm's compliance (i.e. effectiveness) as the following:

a. *Cost equation*:

$$\mathbf{C_{it}} = \Delta \mathbf{c_{it}} + \boldsymbol{\varphi} \mathbf{x_{it}} + \boldsymbol{\varepsilon_{it}} \quad (1)$$

Where **C** is total annual inspection costs[4] of a firm; subscript *i* is an index for the firm and *t* is for time (in years). Therefore, $\varepsilon_{it}$ is an idiosyncratic error term – i.e. changes over time as well as across the individual firms under observation – which captures all unobserved difference among the firms (Baltagi 2008a).

[4] Detailed description of cost and compliance variables is given in next section

$\Delta \mathbf{c}_{it}$ is an incremental[5] annual subsidy cost attributed to the inspections of the firm. The **X** is a set firm-specific control covariates, including firm's production output, hours of inspection required and its compliance history such hygiene scores achieved and enforcement action takes against the firm for any breaches of the hygiene rules. φ is a vector of parameters of the explanatory variables.

b. *Compliance or effectiveness equation*:

$$\mathbf{E}_{it} = \Delta \mathbf{e}_{it} + \boldsymbol{\varphi} \mathbf{x}_{it} + \boldsymbol{\varepsilon}_{it} \tag{2}$$

Where **E** is the annual enforcement actions takes against a firm which a dependent variable here; subscript *i* is again an index for the firm and *t* is for time (in years). $\Delta \mathbf{e}_{it}$= annual incremental[6] compliance scores achieved by a firm.

The **X** is a set control covariates, including firm's production output, annual changes and subsidies costs and hours of inspection service used. φ is again a vector of parameters of the covariate variables.

**6. Data**

Data is extracted from the Meat Hygiene Service's data systems for inspection costs and compliance records for approved Great Britain meat plants. This data is anonymous and does not contain any firm-specific information such as names and locations of the companies concerned. Thus, analysis that will follow refers to sectoral costs and compliance rather than to a specific meat firm.

For consistency, we selected data for 2001 to 2008 period which is collected under the leadership of the FSA[7]. The MHS partially charges all approved abattoirs and meat cutting

[5] Incremental annual subsidy is the difference between annual subsidies in year 2 minus year 1 and so forth until year 8

[6] Incremental compliance scores are the difference between annual scores in year 2 minus year 1; so forth until year 8

plants for using its hygiene and animal welfare inspections as required by the official controls finance provisions set out in Articles 26 and 27 of Regulation (EC) No. 882/2004 (MHS 2008). For abattoirs, these charges are based on number of animals slaughtered, whereas for meat cutting and packing plants the charges are calculated on the basis of volume of meat processed. The remaining inspection costs incurred by the MHS are borne by the government as annual subsidy to the enforcement of official controls of meat hygiene (Food Standards Agency 2008). Items of a particular theoretically and empirical interests are the annual total costs of inspections at a plant-level (i.e. sum of the annual charges and subsidies attributable to the firm); firms' inspection charges and subsidies attributes to its activities; firm's production throughput; and hours of inspection required by each firm audited over 8 years covering period 2001-2008, inclusive.

We theoretically assume that the regulator (FSA) and meat firms are minimising their delivery and compliance costs respectively. Empirically, the escalating costs of the official controls are, on the one hand, the driving force of ongoing regulatory reforms of meat inspection regime to cost-effectively protect the public health (Food Standards Agency 2008). On the other hand, the meat industry has long contested that the administrative and cost burdens of the official controls in general and more specifically the industry charges are hampering their sectors' competitiveness (Pooley 1999; Maclean 2000; Tierney 2007). Therefore, the cost data collected is relevant for the analysis cost-effectiveness of the enforcement modes in relation to regulators' enforcement decision-making and firm's compliance behaviour. A full description of the variables for these relevant items and their descriptive statistics are provided in table 1 and 2 respectively, see appendix.

The compliance data is similarly extracted from the MHS data systems for hygiene scores and enforcement actions takes against a firm found in breach of the rules. Specifically, compliance scores are from the Hygiene Assessment Scheme (HAS) and Audits Category (AC) records. HAS is a risk-based method of assessing hygiene standards at licensed slaughterhouses and cutting plants (Food Standards Agency 2003). It was introduced in 1995, the first year of

[7] Prior to establishment of the FSA, the MHS was part of the old Ministry of Agriculture, Fisheries and Food (MAFF)

operation of the MHS with four main purposes: to measure the hygiene standards in all slaughterhouses and cutting plants, as a baseline for identifying future progress; as a tool for directing enforcement effort; as a management tool for monitoring hygiene risks, and to ensure that there exists a common hygiene standard across the UK (Garcia  and Jukes 2008). Until end of 2005, the official veterinarians looked at various hygiene aspects of a plant's structure, equipment and operation and awarded each aspect a mark according to a published set of guidance notes from which an overall HAS score of between 0 and 100 points was calculated.

From 1st January 2006, when a new consolidated EU hygiene legislation came into effect in the UK (Food Standards Agency 2005b), the HAS system is replaced by a new more risk-based audit system (Food Standards Agency 2008a). This new system shifted official inspectors' role from the traditional visual inspection and supervision under the HAS, to auditing and verification of firm's food safety management systems (Meat Hygiene Service 2007). Particularly, the new audit system, which implements the new EU food law making explicitly food safety the primary responsibility of the food business operators (European Commission 2002), focuses the effort of the official inspections on two types of risk factors. First type of risk factor relates to the meat establishments in relation to production activities and nature of the food business. A second type of risk factor relates to control actions undertaken by the firm and its food safety assurance systems (Food Standards Agency 2008a). A score of up to 120 points is awarded for each of the two risk factors, with the total score determining the audit category (5 different categories in total) and in turn the appropriate frequency of auditing for a firm which can range from 2 to 12 months. Therefore, hypothetically, such risk-based system is less regimental than the HAS and therefore the audit system reduces enforcement costs and firm's compliance costs, creating incentives for cost-effectively improved food safety.

We calculated average annual of HAS and audit scores for each meat firm inspected in the period 2001-2008, whilst cost data is already accounted as annual figures. As a result, the subscripts of the specified panel model become i= 1, 2, 3…710[8] and t=8.

[8] We obtained full cost and compliance data for 710 meat plants over the 8 years period of interest

Therefore, we use a panel data of the regulatory costs and compliance scores of the meat firms over 8 years. Such panel analyses of the data consents for controlling unobserved heterogeneity of meat firms' in their cost and compliance decision-making. It is well known that food firms differ in their technical efficiency, financial resources and managerial skills – issues that may be an underlying cause of observed differences in firms' compliance costs and scores (Antle 1999; Unnevehr 2000; Hoffmann and Taylor 2005). A second advantage of the panel analysis is that it permits comparative evaluation of firms' adjustments to the regulatory changes that occurred in 2006 (Wooldridge 2002; Greene 2008). Adjustment to the regulatory changes may also have lead to differentially lower compliance costs (i.e. charges and subsidies) over time as firms would in their ability to take advantage of the more flexible new consolidated official controls (Unnevehr and Jensen 2005). In addition to being more informative about heterogeneity of the firms, the pooled panel data analysis also gives less collinearity problems among the variables and more degrees of freedom and consequently efficiency (Baltagi 2008a) compared, for example to time series and/or cross-section analysis of the data (Wooldridge 2002).

## 7. Analysis

We analyse data using STATA's software package fixed-effects estimator. The fixed-effect model allows isolating and eliminating the individual firm-specific differences ($\alpha_i$) among firms operating in the same sector – for example, the above mentioned possible underlying differences in firms' observed heterogeneity in relation to cost and compliance decision-makings. In effect, the approach allows controlling for any firm-specific effects that may exist among firms operating within a sector governed by the same regulatory approach and therefore consent for unbiased comparison of the firms across a sector based on the magnitude of the coefficients of interest (see Wooldridge 2002; Greene 2008; Baltagi 2008a). Additionally, the fixed-effects model has the advantage of consenting for consistent estimation of parameters of interest even if regressors are partially correlated with the error term $\varepsilon_{it}$ (Baltagi 2008a), providing that this correlation is attributable to the fixed-effect – related component of the error term ($u_i$) (Wooldridge 2002). For example, unlike the red meat sector, food industry and poultry sector is dominated by large companies that may control a number of smaller firms by either contractual coordination or ownership (Anonymous 2006). Thus, it is reasonable to expect the cost and compliance decision-makings of these firms are interlinked, potentially entailing serial correlations of the error terms in time and across the firms. In these circumstances, the fixed-effects model that deals with such issues by eliminating firm-specific differences is theoretically appealing.

Nevertheless, it is common practice to run corresponding random-effects models for each panel equation to ascertain the appropriateness of the fixed-effects model based on the data properties rather than theoretical intuition (Wooldridge 2002). Hausman (Baltagi 2008a , p22) and Chamberlain/ Mundlak specification tests are routinely used to check the appropriateness of the fixed-effects model against the random-effects model (Wooldridge 2002, p288-91). Both specification tests rejected the null hypothesis that observed differences among firms operating within a sector governed by a particular mode of regulation are purely due to by a random or stochastic phenomena. Therefore, in line with our theoretical expectation, there are significant differences in the way meat firms use the inspection service in relation to their compliance and cost decision-makings.

For the cost model, we regresss the firm's total annual cost of inspections **(Total_Annual cost)** on the incremental annual subsidy cost **(annual_subsidy)** which is the variable of primary interest in this case. To control for individual firms' heterogeneity, we include into the panel model the set of the above mentioned firm-specific covariates, including firm's production output **(output)**, hours of inspections **(hours),** average compliance scores achieved **(agr_score)** and number of enforcement actions taken against the firm where it is found to be in breach of the hygiene rules (**enforcement**).

We also include into the cost model a variable for subsidy cost per unit of output (**unit_subscost**) and its quadratic term (**unit_subscost2**) to measure the diminishing effects of the subsidy per output unit on the total cost (Baltagi 2001; Greene 2008). As mentioned above, public subsidies are injected into the official controls to meet the annual operational deficit of the MHS because of the partial recovery of the costs from industry. Therefore, from efficiency perspective, it is worth measuring the effects of the per unit subsidy cost on the total costs of the inspections under the different enforcement models understudy.

For the compliance model, regress the enforcement actions on the incremental compliance scores, which is the variable of primary interest in this case. To control for heterogeneity among firms, we include into the model the covariates for firm's output, hours of inspection required, annual charges and annual subsidy.

Theoretically, for the cost model, we would expect that the incremental subsidy cost and compliance scores, output and hours of inspections are all positively related to the total inspection costs regardless of whether a firm is operating in the poultry or red meat sectors. In other words, we expect that the total inspection costs increase as these variables increase. For example, it is reasonable to expect that increases in the annual output and resulting higher hours of inspection required would entail higher annual total inspection costs and consequently incremental subsidy, whereas changes in the per unit subsidy cost would depend on firm's ability to take advantage of its increased economy of scale. Similarly, higher inspection costs from increased hours of inspection would improve the incremental compliance scores compliance over time. To put it differently, the compliance scores are expected to positively relate to the annual total cost as the latter increases the hours of inspection, holding constant firm's output. Enforcement actions taken against a firm are instead expected to be negatively related to the annual total inspection costs, because of the higher presence of official inspectors and frequency of enforcement attention given to a firm's compliance behaviour. This is particularly true for the inspections under the new regime which places emphasis on the verification and monitoring of firm's food safety management practices.

For the compliance model, we would expect that higher enforcement actions in a year would induce improved compliance scores next year. Equally, higher enforcement actions would increase subsidy costs as result of increased hours of inspections, holding output constant. The output is likely to be positively related to the enforcement actions, due to possible diversion of the PIAs effort away from auxiliary tasks to production activities where alternative arrangements are not been made and/or official veterinarian supervision is inadequate. This potential dual responsibility in a PIA's role as an auxiliary inspector and production staff in effect entails the above discussed incentive incompatibility under the co-regulation. Thus, the regulator is forced to trade efficiency against possible rent extraction by some operators who may underperform the auxiliary tasks whilst claiming full cost compensation for these tasks (Laffont and Tirole 1993; Laffont and Martimort 2002).

## 8. Results and Discussion

The results of the pooled fixed-effects models for cost and compliance equations are presented in the appendix see tables 3-6, whereas the output of the same models for the adjustment to post 2006 regulatory changes in provided in tables 7-10. A cost-effective ratio is calculated from the coefficients for the incremental annual subsidy and compliance scores obtained from these analyses to compare the two enforcement modes understudy. A summary of the ratios is produced in table 11.

Table 11: cost-effectiveness ratios

| | **Sector** | **Incremental subsidy cost ($\Delta c_{it}$)** | **Incremental compliance scores ($\Delta e_{it}$)** | **Cost-effectiveness Ratio = $\Delta c_{it}/\Delta e_{it}$** |
|---|---|---|---|---|
| **pooled panel** | Co-regulated poultry | 0.408 (0.081) | 0.106 (0.045) | **3.85** |
| | Red meat | 0.534 (0.058) | 0.171 (0.022) | **3.12** |
| **Adjustment 2006** | Co-regulated poultry | 0.294* (0.143) | 0.172 (0.033) | **1.71** |
| | Red meat | 0.706 (0.056) | 0.279 (0.028) | **2.53** |

* All coefficients are significant at 99%, with exception to asterisk marked which is significant at 95%.

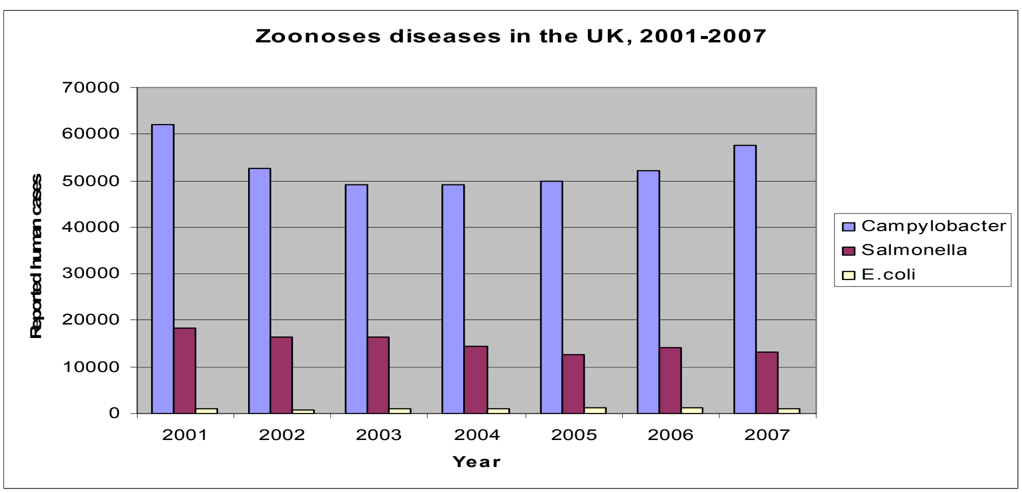
On overall, the results of the pooled fixed-effects models show that the coefficients for the variables of primary interest (i.e. incremental annual subsidy and compliance scores) have the expected signs and are significant at 95% in all models (see tables 4-9). The standard errors have reasonable sizes relative to the respective coefficients. F tests for the models fitness are all significant at below 97%, suggesting that these models explain data well. The lower part of the regression outputs show that null hypotheses that the error component (ui) attributable to firm-specific or fixed effects is rejected for all models. Therefore, as anticipated, meat firms significantly differ in their cost and compliance decision-makings in relation to the use of food hygiene inspection services.

Table 11 shows that the co-regulatory delivery model for poultry controls is less cost-effective (£3.85/unit of compliance score) than the command-and-control (£3.12/unit of compliance score). However, the poultry firms adjusted the regulatory changes far better than the red meat sector did with respective cost-effectiveness ratios of 1.71 and 2.53. The lower cost-effectiveness of the poultry sector is largely due to its relatively poorer compliance. In effect, the coefficient for the annual incremental subsidy costs of the co-regulatory poultry model (0.41) is approximately 27% lower than the same coefficient for the red meat CAC model (0.534). However, the coefficient for the incremental compliance scores of the red meat poultry (0.171) is considerably (47%) higher than the same coefficient for the co-regulation model (0.106). Therefore, although the poultry absorbs relatively lower annual incremental subsidy costs, the red meat performs better in compliance terms compared to poultry.

These findings can be explained by incentive incompatibility problems arising from delegation of official auxiliary task under co-regulation. As mentioned earlier, unlike the red meat firms, a poultry firm is permitted to use its own staff to carry out substantial auxiliary tasks, including important ante and post mortem hygiene controls of animal carcasses under the supervision of an official veterinarian. It is reasonable to expect that these plant inspectors are more accountable to firm management than the supervising official veterinarian, and are also more familiar with activities they control than the official veterinarian who may be deployed in different plants as required (Food Standards agency 2007c; MHS 2008). Therefore, there is considerable information and authority asymmetry between the official veterinarians and plant inspectors/managers. In these circumstances, the firm can use its authority and informational advantage over the official controllers to extract rents from the regulator by, for example, using the PIAs for non-auxiliary tasks to minimise its production whilst in effect these costs are paid for regulator as reimbursements for the delegated official tasks. The result is that the flexibility enjoyed by the poultry operators in deploying its own inspectors translates into lower annual throughput charges (and consequently incremental subsidy) accompanied by a poor compliance performance.

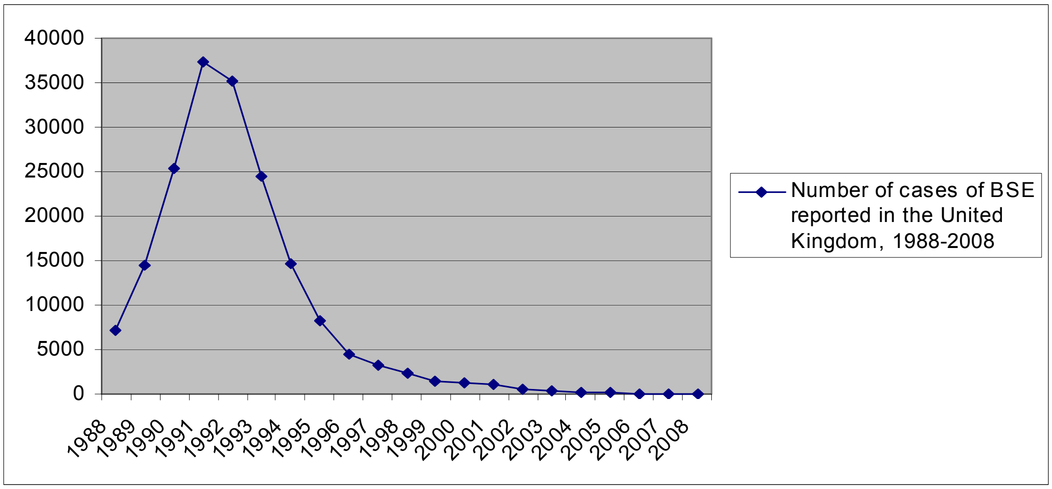
In effect, although co-regulated poultry firm can achieve considerable cost-efficiency, the use of own staff does not necessarily improve its compliance performance due to underlying incentive problems. As shown in table 11, poultry firm's incremental compliance scores (0.11) brought by increased official enforcement actions taken against it for breaches for hygiene rules is considerably (47%) lower than those achieved in red meat a firm (0.17). Thus, enforcement corrective actions are not effectively implemented in poultry firms compared to red meat firms. Therefore, our theoretical proposition that, without a well crafted regulatory incentive mechanism to ensure governance, a co-regulatory delivery of official controls of meat hygiene would be sub-optimal is confirmed. The informational asymmetry between the official inspectors and plant inspector/firm managers weakens the governance of the enforcement of hygiene rules under the co-regulation.

Chart 2




Source: Defra, http://www.defra.gov.uk/foodfarm/farmanimal/diseases/atoz/zoonoses/reports.htm

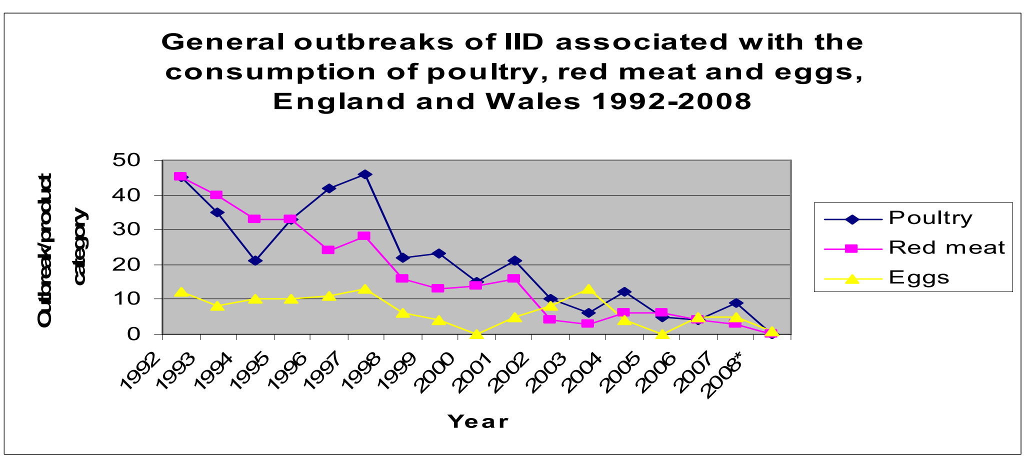
Chart 3




Source: World Organisation for Animal Health, http://www.oie.int/eng/info/en_esbru.htm

These findings are supported by evidence from analysis of reported UK zoonoses diseases and general foodborne disease outbreaks associated with the consumption of the poultry and red meats respectively. Firstly, as shown in chart 2, the Campylobacter and Salmonella which are the two most prevalent zoonotic pathogens associated with poultry meat have been (and remain) high over the 8 years period concerned compared to E. coli and BSE which is more associated with beef and lamb. Chart 3 instead show drastic decline of the BSE in recent times. Thus, poultry risks are considerably higher, for example, the BSE in cattle meat. However, it is worth pointing out that Salmonella is prevalent in pigs (BPEX, Defra et al. 2008) albeit to a lesser degree than poultry (Food Standards Agency 2001; Food Standards Agency 2005).

Char 4




Source: Health Protection Agency

Secondly, as shown in chart 4, the foodborne disease outbreaks associated with poultry meat consumption have been persistently higher than those associated with red meat for over the past 15 years. Therefore, findings of the research depict a true picture of the reality on ground in relation to correlation between observed industry compliance and foodborne disease. There is a consistent relationship between observed industry compliance; reported zoonoses and outbreaks of foodborne disease – a finding which vindicates our choice for using compliance as proxy of foodborne disease.

Further empirical evidence that explains the observed poultry industry under-compliance comes from analysis of the FSA's food safety strategies and annual reports, which highlight considerable difficulties in achieving regulatory goals for reducing foodborne disease associated with poultry meat consumption. In its five-year strategy 2005 -2010, the agency has set a target to achieve a 50% reduction in the incidence of UK produced chickens which test positive for Campylobacter by 2010, from a baseline in 2006 (Food Standards Agency 2005). Subsequently, the Chief Scientist of the agency reported to the Board of Governors that the agency was unable to meet this target due to a large number of foodborne disease cases increasingly caused by Campylobacter and Salmonella (Food Standards Agency 2008c). The Chief Scientist singled out the continual mismatch between the controls necessary for ensuring food safety and the EU meat hygiene regulations. He argued that, although more risk-based than previous legislation, the new EU consolidated hygiene regulation still contain prescriptive requirements with "no basis in science" and still require officials to visually inspect every carcase, when there is "very little of public health significance that can be seen". In addition, by requiring the constant presence of officials tasked with enforcing compliance with the regulations, rather than securing food safety, the prescriptive controls inhibit slaughterhouse operators from taking responsibility for food safety. Therefore, our theoretical preposition that regulatory excessive monitoring of production controls crowds out incentive for compliance is justified.

However, as already cited, the results of the fixed-effect models for adjustment to the hygiene policy changes reveal a significant positive impact on poultry compliance compared to red meat sector. As shown in table 11, the poultry sector outperforms the red meat with cost-effectiveness ratio of 1.71 and 2.53 respectively. Average annual compliance scores of the poultry sector have increased 62% from 0.106 to 0.172, whereas its incremental annual subsidy has fallen 28% from 0.408 to 0.294. Therefore, the hygiene policy changes have considerably improved the efficiency of the co-regulatory enforcement model for poultry. This improvement appear to have resulted from the shift of the inspection emphasis from the traditional from inspection and supervision of production processes to audit and verification of firms' food safety management systems under the new hygiene regime (Food Standards Agency 2006; Meat Hygiene Service 2007). In effect, official inspections are dedicating more time and attention to the monitoring and verification (as opposed to counter-inspection) of tasks performed by the PIAs through auditing of firm's assurance systems. As such the new inspection regime is more capable of alleviating the incentive incompatibility under the co-regulation.

**Conclusion**

The aim of this study was to comparatively quantify cost-effectiveness of a co-regulatory approach to meat hygiene controls. The econometric cost-effectiveness approach adopted here allowed rigorous analysis taking into consideration heterogeneity among meat firm, as well as accounting for possible endogeneity in variables for inspection costs and compliance scores.

The study concludes that co-regulation of food safety control can be a cost-effective way of food safety controls where a regulator is capable of crafting a regulatory mechanism that gives firm the right incentive for compliance. In addition to effective official monitoring and verification, private industry governance schemes that provide incentives for voluntary compliance through third partly accreditation and monitoring may also alleviate incentive problems that arise from delegation of official tasks. These options are currently out of reach for red meat sector as the current EU food legislation does not permit use of plant inspectors for official auxiliary tasks. The current red meat assurance standards which cover food safety appear to be in effective in this case to encourage better compliance due to the regimental inspection regime for the sector which in effect limits firm's ability to seek alternative more cost-effective way of complying with rules.

Therefore, the enforcement model used in this sector is less cost-effectiveness under the new hygiene regime notwithstanding the considerable recent decline of foodborne disease associated with consumption of the red meats in general and more specifically BSE which has underpinned restrictive official controls in cattle meat inspections. These findings call for systematic evaluation of current hygiene controls across the sectors to explore ways of extending co-regulation to other sectors with incentive structures similar to the poultry meat sector. A further research in this field is necessary to establish what need to be changes in the current incentive structures so that co-regulation can be considered for sector that currently do not lend themselves to co-regulation.

A valuable contribution of this study to the existing body of knowledge is that the econometric approach taken consents for rigorous evaluation of cost and benefits of different regulatory strategies without monetising benefits – a task which is difficult per se due to intangibility of benefits of food safety controls. The study also contributes to the current debate on regulatory burdens and the role of the UK official controls of meat hygiene in protecting public health. Given the considerable social costs of the meat hygiene controls and pertinence of these controls for public health protection, perhaps a more enlightened EU policymaking in this area is necessary to enable more regular upgrades of the legislation. For this purpose, sunset clauses can be, for example, incorporated into the primary policy instruments so that controls are appropriately adjusted to changing risk profile and business environment.

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## Appendix

Table 1: Variable description

| variable name | type | format | label | variable label |
|---|---|---|---|---|
| my_id | long | %8.0g | my_id | PANEL ID VARIABLE |
| year | float | %10.0g | | FINANCIAL YEAR (1= 2001/02) |
| pia_costs | float | %9.0g | | REFUNDS FOR USE OF OWN PLANT INSPECTION ASSISTANTS(£) |
| annual_charge | float | %9.0g | | CUMULATIVE ANNUAL COST FOR PLANT(£) |
| annual_subsidy | float | %9.0g | | CUMULATIVE ANNUAL SUBSIDY PER PLANT(£) |
| Total_Annualc~t | float | %9.0g | | TOTAL ANNUAL INSPECTION COSTS(£) |
| output | double | %12.0g | | ANNUAL VOLUME OF PRODUCTION |
| hours | double | %10.0g | | ANNUAL HOURS OF INSPECTION |
| unit_scost | float | %9.0g | | SOCIAL COST PER UNIT OF OUTPUT |
| agr_score | float | %9.0g | | AVERAGE ANNUAL COMPLIANCE SCORE |
| enforcement | float | %9.0g | | TOTAL ANNUAL ENFORCEMENT ACTIONS TAKEN |

Table 2: Descriptive statistics

| Variable | | Mean | Std. Dev. | Min | Max | Observations |
|---|---|---|---|---|---|---|
| my_id | overall | 355.5 | 204.9772 | 1 | 710 | N = 5680 |
| | between | | 205.1036 | 1 | 710 | n = 710 |
| | within | | 0 | 355.5 | 355.5 | T = 8 |
| year | overall | 4.5 | 2.29149 | 1 | 8 | N = 5680 |
| | between | | 0 | 4.5 | 4.5 | n = 710 |
| | within | | 2.29149 | 1 | 8 | T = 8 |
| pia_co~s | overall | 6305.255 | 27502.69 | 0 | 354040.9 | N = 3956 |
| | between | | 20906.49 | 0 | 227533 | n = 702 |
| | within | | 12777.22 | -221227.7 | 169626.9 | T-bar = 5.63533 |
| annual~e | overall | 40450.52 | 82088.96 | 0 | 747297.5 | N = 3956 |
| | between | | 70053.21 | 0 | 468543.4 | n = 702 |
| | within | | 26635.2 | -258357.5 | 420479.2 | T-bar = 5.63533 |
| annual~y | overall | 22750.21 | 47189.54 | 0 | 446448.7 | N = 3956 |
| | between | | 39463.94 | 0 | 264462.4 | n = 702 |
| | within | | 17551.96 | -153709.7 | 256329.4 | T-bar = 5.63533 |
| Total_~t | overall | 69505.98 | 133251.6 | 0 | 1187152 | N = 3956 |
| | between | | 114658.7 | 0 | 807671.4 | n = 702 |
| | within | | 39093.73 | -351224.3 | 459031.4 | T-bar = 5.63533 |
| output | overall | 1732341 | 7274882 | 0 | 8.87e+07 | N = 3759 |
| | between | | 6215984 | 0 | 7.77e+07 | n = 650 |
| | within | | 1002045 | -1.34e+07 | 2.05e+07 | T-bar = 5.78308 |
| hours | overall | 2617.841 | 4447.914 | 0 | 50288.15 | N = 4248 |
| | between | | 3871.711 | 0 | 31293.31 | n = 531 |
| | within | | 2195.108 | -16112.35 | 31298.82 | T = 8 |
| u~_scost | overall | .9112083 | 1.018148 | 0 | 11.27803 | N = 3740 |
| | between | | .9356341 | 0 | 5.478017 | n = 644 |
| | within | | .3379142 | -1.925938 | 9.400552 | T-bar = 5.80745 |
| agr_sc~e | overall | 92.77201 | 27.63744 | 41.5 | 205 | N = 3447 |
| | between | | 16.23571 | 44.95 | 177.1 | n = 592 |
| | within | | 25.14307 | 29.67201 | 206.6887 | T-bar = 5.82264 |
| enforc~t | overall | 11.9179 | 27.07276 | 0 | 445 | N = 3447 |
| | between | | 17.20406 | 0 | 148.4286 | n = 592 |
| | within | | 20.25109 | -117.5107 | 315.4179 | T-bar = 5.82264 |

## Table 3: Fixed-effects co-regulated poultry cost model

```
Fixed-effects (within) regression               Number of obs      =       398
Group variable: my_id                           Number of groups   =        87

R-sq:  within  = 0.7750                         Obs per group: min =         1
       between = 0.9722                                        avg =       4.6
       overall = 0.9593                                        max =         7

                                                F(7,304)           =    149.60
corr(u_i, Xb)  = -0.8911                        Prob > F           =    0.0000
```

| Total_Annu~t | Coef. | Std. Err. | t | P>\|t\| | [95% Conf. | Interval] |
|---|---|---|---|---|---|---|
| annual_sub~y | | | | | | |
| D1. | .4077535 | .0811523 | 5.02 | 0.000 | .2480622 | .5674449 |
| unit_subcost | 1.43e+07 | 1921185 | 7.45 | 0.000 | 1.05e+07 | 1.81e+07 |
| unit_subco~2 | -8.35e+08 | 1.87e+08 | -4.46 | 0.000 | -1.20e+09 | -4.67e+08 |
| output_d100 | 1.12038 | .0502404 | 22.30 | 0.000 | 1.021517 | 1.219243 |
| hours_m10 | .057097 | .0713669 | 0.80 | 0.424 | -.0833385 | .1975326 |
| agr_sco~1000 | .0034167 | .0470055 | 0.07 | 0.942 | -.0890806 | .0959141 |
| enforce~1000 | -.1806263 | .060727 | -2.97 | 0.003 | -.3001248 | -.0611277 |
| _cons | -19342.18 | 5700.354 | -3.39 | 0.001 | -30559.33 | -8125.037 |
| sigma_u | 47729.062 | | | | | |
| sigma_e | 16038.056 | | | | | |
| rho | .89854416 | (fraction of variance due to u_i) | | | | |

F test that all u_i=0:     F(86, 304) =      8.85             Prob > F = 0.0000

## Table 4: Fixed-effects co-regulated poultry compliance model

```
Fixed-effects (within) regression               Number of obs      =       395
Group variable: my_id                           Number of groups   =        87

R-sq:  within  = 0.0410                         Obs per group: min =         1
       between = 0.0425                                        avg =       4.5
       overall = 0.0239                                        max =         7

                                                F(5,303)           =      2.59
corr(u_i, Xb)  = -0.6538                        Prob > F           =    0.0259
```

| enforce~1000 | Coef. | Std. Err. | t | P>\|t\| | [95% Conf. | Interval] |
|---|---|---|---|---|---|---|
| agr_sco~1000 | | | | | | |
| D1. | .1062201 | .0445169 | 2.39 | 0.018 | .0186186 | .1938216 |
| output_d100 | .0972624 | .0523756 | 1.86 | 0.064 | -.0058036 | .2003284 |
| hours_m10 | -.0203879 | .0668097 | -0.31 | 0.760 | -.1518576 | .1110818 |
| annual_cha~e | .4511797 | .188035 | 2.40 | 0.017 | .0811599 | .8211996 |
| annual_sub~y | -.8002172 | .3092907 | -2.59 | 0.010 | -1.408847 | -.1915875 |
| _cons | 3910.154 | 4249.704 | 0.92 | 0.358 | -4452.515 | 12272.82 |
| sigma_u | 16118.445 | | | | | |
| sigma_e | 15018.16 | | | | | |
| rho | .53529328 | (fraction of variance due to u_i) | | | | |

F test that all u_i=0:     F(86, 303) =      3.21             Prob > F = 0.0000

Table 5: Fixed-effects model for red meat costs

| | | | |
|---|---|---|---|
| Fixed-effects (within) regression | | Number of obs = | **2008** |
| Group variable: **my_id** | | Number of groups = | **341** |
| R-sq: within = **0.6657** | | Obs per group: min = | **1** |
| between = **0.7518** | | avg = | **5.9** |
| overall = **0.7445** | | max = | **7** |
| | | F(**7**,**1660**) = | **472.13** |
| corr(u_i, Xb) = **0.2211** | | Prob > F = | **0.0000** |

| Total_Annu~t | Coef. | Std. Err. | t | P>\|t\| | [95% Conf. | Interval] |
|---|---|---|---|---|---|---|
| annual_sub~y | | | | | | |
| D1. | **.534068** | **.0579845** | **9.21** | **0.000** | **.4203375** | **.6477985** |
| unit_subcost | **94773.57** | **9064.618** | **10.46** | **0.000** | **76994.28** | **112552.9** |
| unit_subco~2 | **-11158.65** | **3235.549** | **-3.45** | **0.001** | **-17504.84** | **-4812.465** |
| output_d100 | **72.35447** | **1.613497** | **44.84** | **0.000** | **69.18976** | **75.51917** |
| hours_m10 | **-.3393885** | **.0292577** | **-11.60** | **0.000** | **-.3967743** | **-.2820027** |
| agr_sco~1000 | **.0327623** | **.020867** | **1.57** | **0.117** | **-.008166** | **.0736906** |
| enforce~1000 | **-.0099488** | **.0250277** | **-0.40** | **0.691** | **-.0590381** | **.0391404** |
| _cons | **-7660.62** | **4038.821** | **-1.90** | **0.058** | **-15582.34** | **261.0988** |
| sigma_u | **70488.092** | | | | | |
| sigma_e | **23910.912** | | | | | |
| rho | **.89680497** | (fraction of variance due to u_i) | | | | |

F test that all u_i=0: F(**340**, **1660**) = **35.00** Prob > F = **0.0000**

Table 6: Fixed-effects compliance model for red meat

| | | | |
|---|---|---|---|
| Fixed-effects (within) regression | | Number of obs = | **1993** |
| Group variable: **my_id** | | Number of groups = | **340** |
| R-sq: within = **0.0783** | | Obs per group: min = | **1** |
| between = **0.0891** | | avg = | **5.9** |
| overall = **0.0717** | | max = | **7** |
| | | F(**5**,**1648**) = | **28.00** |
| corr(u_i, Xb) = **0.0575** | | Prob > F = | **0.0000** |

| enforce~1000 | Coef. | Std. Err. | t | P>\|t\| | [95% Conf. | Interval] |
|---|---|---|---|---|---|---|
| agr_sco~1000 | | | | | | |
| D1. | **.1714163** | **.0216096** | **7.93** | **0.000** | **.1290312** | **.2138015** |
| output_d100 | **-.192941** | **2.246755** | **-0.09** | **0.932** | **-4.599737** | **4.213855** |
| hours_m10 | **.1728803** | **.0270881** | **6.38** | **0.000** | **.1197495** | **.2260111** |
| annual_cha~e | **-.1511827** | **.0948213** | **-1.59** | **0.111** | **-.3371657** | **.0348003** |
| annual_sub~y | **.1859566** | **.1218659** | **1.53** | **0.127** | **-.0530717** | **.4249849** |
| _cons | **9768.171** | **1825.489** | **5.35** | **0.000** | **6187.648** | **13348.69** |
| sigma_u | **21143.983** | | | | | |
| sigma_e | **23003.694** | | | | | |
| rho | **.45794984** | (fraction of variance due to u_i) | | | | |

F test that all u_i=0: F(**339**, **1648**) = **4.89** Prob > F = **0.0000**

## Table 7: post-2006 cost model for poultry

| | | | |
|---|---|---|---|
| Fixed-effects (within) regression | | Number of obs = | **193** |
| Group variable: **my_id** | | Number of groups = | **65** |
| R-sq: | within = **0.7275** | Obs per group: min = | **1** |
| | between = **0.9804** | avg = | **3.0** |
| | overall = **0.9732** | max = | **4** |
| | | F(**7**,**121**) = | **46.15** |
| corr(u_i, Xb) | = **-0.8180** | Prob > F = | **0.0000** |

| Total_Annu~t | Coef. | Std. Err. | t | P>\|t\| | [95% Conf. | Interval] |
|---|---|---|---|---|---|---|
| annual_sub~y | | | | | | |
| D1. | **.2936869** | **.1486145** | **1.98** | **0.050** | **-.0005346** | **.5879085** |
| unit_subcost | **7242664** | **3339544** | **2.17** | **0.032** | **631156.1** | **1.39e+07** |
| unit_subco~2 | **1.62e+08** | **4.20e+08** | **0.39** | **0.700** | **-6.70e+08** | **9.95e+08** |
| output_d100 | **1.074971** | **.0824707** | **13.03** | **0.000** | **.9116983** | **1.238243** |
| hours_m10 | **.0792023** | **.1207991** | **0.66** | **0.513** | **-.1599515** | **.3183561** |
| agr_sco~1000 | **.0410629** | **.06431** | **0.64** | **0.524** | **-.0862558** | **.1683815** |
| enforce~1000 | **-.268544** | **.1122747** | **-2.39** | **0.018** | **-.4908215** | **-.0462665** |
| _cons | **-13594.53** | **10461.25** | **-1.30** | **0.196** | **-34305.34** | **7116.285** |
| sigma_u | **39481.393** | | | | | |
| sigma_e | **15770.067** | | | | | |
| rho | **.86240753** | (fraction of variance due to u_i) | | | | |

F test that all u_i=0: F(**64**, **121**) = **4.29** Prob > F = **0.0000**

## Table 8: post-2006 fixed effects compliance model for co-regulated poultry

| | | | |
|---|---|---|---|
| Fixed-effects (within) regression | | Number of obs = | **129** |
| Group variable: **my_id** | | Number of groups = | **53** |
| R-sq: | within = **0.3098** | Obs per group: min = | **1** |
| | between = **0.0306** | avg = | **2.4** |
| | overall = **0.0234** | max = | **3** |
| | | F(**5**,**71**) = | **6.37** |
| corr(u_i, Xb) | = **-0.7565** | Prob > F = | **0.0001** |

| enforce~1000 | Coef. | Std. Err. | t | P>\|t\| | [95% Conf. | Interval] |
|---|---|---|---|---|---|---|
| agr_sco~1000 | | | | | | |
| D1. | **.1721469** | **.0327664** | **5.25** | **0.000** | **.1068125** | **.2374814** |
| output_d100 | **.1048274** | **.0636938** | **1.65** | **0.104** | **-.0221744** | **.2318291** |
| hours_m10 | **-.0316483** | **.1515834** | **-0.21** | **0.835** | **-.333897** | **.2706003** |
| annual_cha~e | **-.1245979** | **.3263269** | **-0.38** | **0.704** | **-.7752753** | **.5260795** |
| annual_sub~y | **.2064896** | **.5454531** | **0.38** | **0.706** | **-.8811129** | **1.294092** |
| _cons | **-1336.685** | **5882.736** | **-0.23** | **0.821** | **-13066.53** | **10393.16** |
| sigma_u | **20838.879** | | | | | |
| sigma_e | **8869.9852** | | | | | |
| rho | **.84661496** | (fraction of variance due to u_i) | | | | |

F test that all u_i=0: F(**52**, **71**) = **3.01** Prob > F = **0.0000**

## Table 9: post-2006 cost model for red meat

| | | | |
|---|---|---|---|
| Fixed-effects (within) regression | | Number of obs = | **1093** |
| Group variable: **my_id** | | Number of groups = | **300** |
| R-sq: | within = **0.6835** | Obs per group: min = | **1** |
| | between = **0.7645** | avg = | **3.6** |
| | overall = **0.7556** | max = | **4** |
| | | F(**7**,**786**) = | **242.51** |
| corr(u_i, Xb) | = **0.6133** | Prob > F = | **0.0000** |

| Total_Annu~t | Coef. | Std. Err. | t | P>\|t\| | [95% Conf. | Interval] |
|---|---|---|---|---|---|---|
| annual_sub~y | | | | | | |
| D1. | **.7055288** | **.0562288** | **12.55** | **0.000** | **.5951524** | **.8159052** |
| unit_subcost | **43196.62** | **12756.08** | **3.39** | **0.001** | **18156.61** | **68236.63** |
| unit_subco~2 | **8289.351** | **4800.015** | **1.73** | **0.085** | **-1133.014** | **17711.72** |
| output_d100 | **47.74981** | **2.131766** | **22.40** | **0.000** | **43.56518** | **51.93444** |
| hours_m10 | **-.2712805** | **.023152** | **-11.72** | **0.000** | **-.3167277** | **-.2258334** |
| agr_sco~1000 | **.0199981** | **.0188309** | **1.06** | **0.289** | **-.0169667** | **.056963** |
| enforce~1000 | **-.0283969** | **.0237689** | **-1.19** | **0.233** | **-.075055** | **.0182612** |
| _cons | **35741.95** | **5851.938** | **6.11** | **0.000** | **24254.67** | **47229.23** |

Table 10: post-2006 fixed effects compliance model for red meat

```
Fixed-effects (within) regression               Number of obs      =       797
Group variable: my_id                           Number of groups   =       283

R-sq:  within  = 0.2330                         Obs per group: min =         1
       between = 0.0022                                        avg =       2.8
       overall = 0.0449                                        max =         3

                                                F(5,509)           =     30.93
corr(u_i, Xb)  = -0.4934                        Prob > F           =    0.0000

------------------------------------------------------------------------------
enforce~1000 |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
agr_sco~1000 |
         D1. |   .2786425   .0280762     9.92   0.000     .2234831     .333802
 output_d100 |   4.754928   6.406258     0.74   0.458    -7.831034    17.34089
   hours_m10 |   .0320578   .0393097     0.82   0.415    -.0451715    .1092871
annual_cha~e |  -.2874746   .1973087    -1.46   0.146    -.6751143     .100165
annual_sub~y |    .130013   .2997404     0.43   0.665    -.4588676    .7188936
       _cons |    16317.2    5340.11     3.06   0.002     5825.831    26808.57
-------------+----------------------------------------------------------------
     sigma_u |  25428.955
     sigma_e |  23974.526
         rho |  .52941433   (fraction of variance due to u_i)
------------------------------------------------------------------------------
F test that all u_i=0:     F(282, 509) =     1.93            Prob > F = 0.0000
```