On The Efficiency of Management-Based Regulation: A Case Study of the UK Poultry Inspection Regime

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Abstract

Food safety is a key policy area that has recently witnessed substantial alignment of risk profiles and regulatory interventions. More risk-based and flexible approaches to food safety controls are increasingly adopted to ensure that greater emphasis is placed upon incentives for compliance through, for example, use of preventive food safety management systems aimed at encouraging food firms to manage risk associated with their products and processes.

Among the new regulatory approaches are Management-Based (MB) strategies which are implemented in food and environmental safety controls. However, there is surprisingly no published research that empirically evaluates the efficiency of the strategy in food policy areas applied. In this paper, we first develop a mixed principal-agent model to study the incentives for efficient provision of food safety under a MB regime adopted to enforce EU food hygiene legislation in the UK poultry sector. We then econometrically test the corollary propositions of the theoretical model by using rich panel data on inspection costs and compliance records for the firms governed by the regime. Findings indicate that the MB regime entails significant losses of regulatory efficiency due to sizeable economic rents appropriated by the firms through underperformance in delegated official hygiene controls.

Keywords: Efficiency, management-based regulation; food safety, incentives; panel data modelling.

JEL codes: C23, K32, Q18, Q28

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1. Introduction

The regulatory approaches combining public and private control activities have recently enjoyed a degree of popularity in Europe and North America. A number of existing measures in environmental protection (Coglianese and Lazer, 2003) and media (Verbruggen, 2009) and food safety controls (Coglianese and Lazer, 2003, Ollinger and Moore, 2009) already incorporate self-regulatory features that are either partly designed and/or enforced by industry actors to supplement official controls. Among these new approaches is the MB regulation which requires the regulated entities to flexibly engage in their own internal planning and rulemaking efforts aimed toward delivering efficiently a particular social good such as clean environment or food safety (Balleisen, 2009, Coglianese, 2010). In doing so the regulatory authorities implicitly vest responsibility in the industry actors who may possess the information and knowledge necessary to design effective controls of food processes, and therefore may be best placed to efficiently achieve the social goals. Such reliance of private actors almost always occurs at least partly as a means of reducing the public costs of regulation, and sometimes reflects antagonism to the use of state power (Balleisen and Eisner, 2009). In both cases, the underlying reasoning is that the flexibility afforded to business is expected to align the firm's commercial goals with the intended social objectives and as a result induce compliance beyond what would be possible under traditional forms of regulation.

Archetypical model of such MB regulation is the current inspection regime for poultry abattoirs. Typically, a poultry firm capable of meeting a pre-specified risk-based criteria (as described below) can partly self-enforce the hygiene regulation (European Commission, 2004). At the same time, the regulator retains a substantial oversight of the firm's self-enforced controls through a combination of mandatory requirements for approval of its internal rules and monitoring of its processes to ascertain compliance. To secure the approval for self-enforcement of rules the poultry abattoirs must have an established HACCP[3] system and appropriate level of staff training (Food Standards Agency, 2007). The approved firms are allowed to use their staff members, Plant Assistant Inspectors (PIAs), as opposed to public meat hygiene inspectors, to carry out a number of delegated official 'auxiliary' tasks[4]. The firms perform the delegated tasks under the supervision of an official veterinarian and in return receive financial compensation (European Commission, 2004, Food Standards Agency, 2007).

The challenge for this type of regulation arises because private actors tend to underproduce social goods such as food safety, thus creating a need for the regulator to intervene to correct the resulting market failure (Viscusi et al., 2000). In particular, there are uncertainties about whether the existing EU regulatory governance systems are robust enough to effectively commit the firms to the intended social goal of safe meat supply. Two key features of the inspection regime, which is currently used in the UK and a number of other member states, especially raise questions about its ability to safeguard meat safety. First, the regime fundamentally entails a principal-agent relationship as the regulator delegates substantive

[3] Acronym for Hazard Analysis Critical Control Point, which is a preventive food safety management tool for hazard identification, mitigation and monitoring and correcting resulting foodborne risks. It specifies key elements that the firm's control plan should have, such as the criteria for identification of hazards associated with its activities, mitigation and monitoring of risk posed, as well as necessary corrective actions necessary when food production processes are not appropriately controlled.

[4] These delegated official tasks include auditing activities to collect information regarding good hygienic practices and HACCP-based procedures of the meat plant, ante-mortem checks of animals and post-mortem inspections of carcasses.

official inspection responsibilities to poultry firms operating under the regulator's supervision and compensation (Laffont and Martimort, 2002, Laffont and Tirole, 1993). The imperfect nature of meat safety outcomes of the delegated tasks and the practical difficulties for the regulator to devise a cost-effective monitoring strategy to verify compliance may in particular reduce the efficiency of the enforcement regime (Henson and Traill, 1993, Starbird, 2005).

Second, the official tasks performed by PIAs are likely to result in varied meat safety outcomes across the poultry sector given that the regulated firms inherently differ in their technical skills and food safety management practices. Large meat firms with sufficient in-house expertise and resources are likely to be more able to design and implement the preventive systems such HACCP and hence find it less onerous to comply with rules compared the smaller firms (Unnevehr and Jensen, 2005, Antle, 2000). Therefore, the combination of imperfect meat safety and the heterogeneity among the firms raise questions as to whether a MB strategy can efficiently ensure meat safety across the UK poultry sector. And if it not, it is worth then establishing what need to be changed in the existing incentive structures to improve the efficiency of the regime.

This analysis is pertinent to both UK and EU food policymaking for at least three reasons: first, abattoirs are a critical 'choke point' through which all poultry products move through before entering the food chain (Morris, 2005); therefore effective controls (or lack of them) at this segment of the chain are likely to have a significant implications for public health. Second, evidence shows that poultry meat-bone disease has long been and remains a major public health concern in the UK and EU. In 2009, the poultry meat accounted for 90% and 26% of all confirmed foodborne disease outbreaks respectively caused by *Campylobacter* and *Salmonella* in England and Wales (Health Protection Agency, 2010). *Campylobacter* alone causes sickness in over 300,000 people each year in the UK, with around 15, 000 people admitted to hospital for treatment and 80 people dying every year[5]. Similarly, the European Food Safety Authority (EFSA) has also recently estimated that there are approximately nine million cases of human C*ampylobacteriosis* linked to poultry products each year across the 27 EU member states (EFSA, 2011). Third, the meat hygiene controls paradoxically absorb considerable public and industry resources. In the financial year 2009/10[6], the operational costs of the Meat Hygiene Service (MHS), the agency responsible for the enforcement of EU official controls in the UK fresh meat industry, were £68.1 million (Meat Hygiene Service, 2010). About 35% (approx. £24 million) of the overall costs have been recovered from industry through partial (statutory) service charges set by EU law, whilst the remainder is paid for by the taxpayers as a subsidy to the operational deficit of the MHS.

Therefore, there is a need for a research to establish the possible reasons why the existing EU regime is unable to prevent contaminated poultry meat entering food chain, whilst substantial resources are dedicated to the enforcement of meat hygiene controls in the UK and many other EU member states. In this paper, we attempt to answer these questions by first developing a theoretical principle-agent model to study incentives for compliance under the MB regime and then specifying an econometric model to test the corollary propositions of the theoretical model using a suitable data set. The paper is structured in six sections. After this introduction, we discuss the incentive problems that arise under the partial delegation and compensation in section 2 and then develop a mixed principal-agent model to study tradeoffs faced by the UK regulator enforcing the hygiene rules under imperfect information section 3. In section 4, we specify the econometric panel model to empirically test two main hypotheses

[5] UK Research and Innovation Strategy for Campylobacter − in the food chain 2010-2015

[6] Latest available data

derived from the principal-agent model. The remainder of the paper discusses the results and draws conclusions from analyses.

2. Incentive Incompatibility in Meat Hygiene Controls

The delegation of an official task to a meat firm (agent) with private information inherently brings about an allocative efficiency problem for the UK food safety regulator (principle). The firm's private information can be of two types: either the firm has some knowledge about its cost that is not recognised or is ignored by the principle during approval process, the case of *adverse selection* or hidden knowledge, or the firm can subsequently take action unobserved by the principle, the case of *moral hazard* or hidden action (Laffont and Martimort, 2002). The theory of incentives, and in particular principal-agent paradigm, provides adequate analytical framework to determine optimal ways of coping with the imperfect information which affects regulator's ability to efficiently achieve the social objective(s) encompassed by the delegated task – supply of safety meat.

The principal-agent model has been extensively applied in recent years to study the incentive incompatibility between firm's goals and the provision of food safety under commercial supply contracts. Chalfant et al. (1999) developed a conceptual principal-agent model with an adverse selection problem to study the effects of imperfect information about product grading with errors on returns to producers. Starbird (2005) used a principal-agent model with a moral hazard problem to study the contractual relationship between a buyer and suppliers in relation to food safety assurance. He demonstrated that inspection regimes based on stochastic sampling policies influence the behaviour of suppliers. Similarly, Starbird and Amanor-Boadu (2007) used a principal-agent model in the context of adverse selection to examine how contracts that incorporate product traceability can be used to exclude primary producers who cannot meet a processor's safety specifications. More recently, Goodhue (2011), who has reviewed the economic literature regarding incentive contracts and the provision of food quality, concluded that financial incentives can be effectively used in contract selections when product attributes are easily observable at the point of transaction, whereas requirements for inputs and actions necessary to achieve quality tend to be used at the production stage when an attribute is not easily observable.

Although these studies draw from the analysis of commercial contracts inferences that are relevant to food safety regulation, they do not *per se* examine the incentives for compliance under a regulatory contract, for example, involving a direct relationship between a regulator and a regulated food firm. As today, no published research has, to the best of our knowledge, modelled formally the behaviour of food firms under a regulatory contract with imperfect information and compensation for delegated official tasks. We intend to fill this gap in the research by assessing the impact of potential adverse selection and moral hazard arising from the approval process for the MB enforcement strategy and subsequent performance of the delegated auxiliary tasks respectively. Although the regulator is using a risk-based criteria in this case, a poultry firm would have prior knowledge about its 'type' in relation to its products, processes and practices, as well as cost associated with the delivery of the delegated tasks. In addition to the adverse selection, the approved firm can also subsequently under-perform the delegated official tasks to minimise its compliance cost and as a result entail a moral hazard problem for the regulator (Mirrlees, 1999).

Therefore, under MB regulation and imperfect information, a poultry firm can potentially extract information rents by underperforming the delegated tasks in the knowledge that it is costly for the regulator to adopt extensive monitoring strategy to uncertain the safety outcome

of the self-enforced hygiene controls (Baron and Myerson, 1982). Monitoring is costly in this case because the microbiological safety attributes of meat are by nature difficult to discern without extensive analysis at production stage nor consumers can verify the attributes at the point purchase (Henson and Traill, 1993, Antle, 1995, Shogren, 2003, Unnevehr, 2000). Therefore, the MB enforcement may result in a sub-optimal compliance due to the scope for the firm to redeploy its PIAs away from the delegated official tasks to normal production activities in order to minimise compliance cost. The existing EU rules for the organisation of official controls require a distinct separation of the delegated tasks and production responsibility to limit any overlap of PIAs' roles (European Commission, 2004). However, the approved firms may under-perform the delegated tasks if the supervision by official veterinarians is weak and/or monitoring meat safety is too costly for the regulators and buyers (Vetter and Karantininis, 2002). In support of this argument, a combination of intense price competition in meat supply chains (FT Editorial, 2013) and weak regulatory oversight of abattoirs (Andrew and Pickard, 2013) were linked to the recent incidents of undeclared horse meat partly contaminated with the veterinary drug phenylbutazone entering in the UK and EU meat supply chains.

In these circumstances, the regulator clearly faces a tradeoff between reducing the information rents extracted by the firms and eliciting an acceptable level of effort to ensure meat safety (Laffont, 1995). In effect, the regulator is forced to pay the firm a rent (over and above the efficient price (or compensation) for the delegated auxiliary tasks to induce meat hygiene effort (see Grossman and Hart, 1983, Jewitt, 1988, Holmstrom and Milgrom, 1991, Miller, 2005). We develop a mixed principal-agent model to study the extent to which the adverse selection and moral hazard affect the efficiency of the MB regime for the UK poultry sector. We focus on the incentive leverages the regulator can use to induce the firm to take actions that are conducive to principal's interest – in this case the policy objective of safeguarding meat safety at minimal social cost.

3. Mixed Principal-Agent Model

We modify a mixed principal-agent model originally developed by Laffont (1995) to study the relationship between a regulator and a producer of a risky environmental good which is supplied under a contract with a moral hazard followed by adverse selection. We implement this theoretical model in an inverse contractual setting whereby the regulator first faces an adverse selection problem arising from the approval of a firm for a MB regulation under imperfect information and then designs an optimal enforcement mechanism to alleviate the subsequent moral hazard problem entailed by the delegated tasks.

Let us assume that the regulator uses the risk-based approval criteria at his disposal as a screening devise and can discriminate the inefficient firms (i.e. with poor safety management capability and thus unsuitable for approval for MB regulation) with probability of π. Let us also assume that, once approved, the regulated firm performs the delegated task with the realization of certain meat safety outcome with social value S.

The cost of the MB enforcement regime at a firm level is:

$$C = \beta - e_1 , \qquad (1)$$

Where β is an efficiency characteristic of a firm which, in this case, represent a social cost incurred per unit of inspected output (i.e. a cost structure or type of abattoir) and e_1 is a pre-approval compliance effort variable of the firm; in this case the adoption of HACCP system and training, which affect regulator's enforcement cost. Given the imperfect information and

uncertainty about the agent's ex ante HACCP and staff training activities, an approved firm creates a meat safety risk with probability $1-\pi$ which represents the likelihood of meat-borne risk materialising with a social cost E. The expected value of the MB enforcement strategy is therefore:

$$S-(1-\pi)E \tag{2}$$

The probability of safe meat supply π resulting from a correct approval is subsequently affected by the firm's subsequent choice of a certain meat hygiene control effort level of e_2 which combines with e_1 to create for the firm's a (non-monetary) disutility $\psi(e_{1+}e_2)$. We assume a non-monetary disutility effort in because (a) the pre-approval HACCP and staff training are a legal requirements for any firm opting for MB enforcement under consideration and as such the firm's pre-approval cost accrue as a sunken compliance cost, and (b) the firm receives a full ex post compensation for the delegated auxiliary tasks in this case. We also assume that the two types of effort are perfect substitutes given that the better prepared larger abattoirs with greater economy of scale and superior in-house food safety expertise are likely to both secure approval and find it easier to efficiently perform the delegated tasks, if they wish and/or are compelled to do so, compared less resourced smaller abattoirs (Unnevehr, 2000).

To simplify the analysis we assume that the safety effort e_2 can take only two values, 0 for no PIAs effort and 1 for maximal effort, with $\pi(1)>\pi(0)$. Unlike Laffont who assumed that E is always very large and hence e_2=1, we allow E to vary such that $0<e_2<1$, depending on the compliance behaviour of the firm and effectiveness of the veterinary supervision. Our analysis therefore departs from Laffont's one as we formally model the impact of firm compliance behaviour on the efficiency of the MB regime through scrutiny of the uncertainty about e_2. More specifically, we assume that, on the one hand, there is always a degree of official veterinarian supervision that prevents a complete neglect of hygiene controls even if a firm is performing all official auxiliary tasks. On the other hand, the firm may to have some non-regulatory incentives to ensure meat safety, including concerns about possible product liability and loss of market share and reputation (Caswell, 2005, Antle, 1999, Thomsen and McKenzie, 2001, Salin and Hooker, 2001). The combination of these incentives would prevent e_2 to become trivially small – i.e. a complete neglect of meat hygiene by an abattoir. However, given the scope for deployment of PIAs, these incentives may not necessarily suffice to deter the firm from some degree of under-compliance, especially knowing that it is costly for the regulator to verify safety outcome (Vetter and Karantininis, 2002). Therefore we allow e_2 to vary between extremes.

Let t be a compensation (net) transfer from the regulator to the firm using its PIAs to perform the delegated official auxiliary tasks. The firm's ex post utility level is:

$$U=t-\psi(e_{1+}e_2) \tag{3}$$

The expected social value of the MB enforcement strategy is:

$$V=S-(1-\pi)E-(1+\lambda)(C+t), \tag{4}$$

Where $\lambda>0$ and $1+\lambda$ is the social value of public funds used by the regulator to compensate the firm.

The objective of the regulator can then be written:

$$W = V + U = S - (1 - \pi)(e_2))E - (1 + \lambda)(\beta - e_1 + t) + t - \psi(e_{1+}e_2) = S - (1 - \pi)(e_2))E - (1 + \lambda)(\beta - e_1 + \psi(e_{1+}e_2) - \lambda U \quad (5)$$

Given that the firm's effort is always necessary to ensure meat safety, we assume that the value of function ψ is strictly positive and increasing – that is to say $\psi(0) = 0$, $\psi' > 0$ and $\psi'' > 0$.

Under the imperfect information about firm's type and effort, the regulator cannot observe ex ante C , β and e, but can instead observe ex post the total cost of inspection incurred to enforce rules at a particular firm C and the occurrence of any linked poultry-borne safety incident[7] e. β can therefore take two values in this case, $\overline{\beta}$ for the inefficient agent type and $\underline{\beta}$ for the efficient type, with $\overline{\beta} > \underline{\beta}$ and v = Pr($\beta = \underline{\beta}$).

Applying the revelation principle, a deterministic form of the MB enforcement contract can

be written as a revelation mechanism:

$t^{sa}(\tilde{\beta}), t^{us}(\tilde{\beta}), C(\tilde{\beta})$, which specifies for each announced efficiency characteristic $\tilde{\beta}$ an inspection cost, $C(\tilde{\beta})$ and net transfers t^{us} and t^{sa} for ex post compensation to be received if or not meat-borne incidents attributable to a firm occur respectively.

For an announcement the firm's expected utility is:

$$U(\beta, \tilde{\beta}, e_2) = \pi(e_2)t^{sa}(\tilde{\beta}) + 1 - \pi(e_2)t^{us}(\tilde{\beta}) - \psi(\beta - C(\tilde{\beta}) + e_2)$$

Given the high prevalence of the pathogens associated with poultry meat and the potential severity[8] of public health risks they pose, it is reasonable to assume that E is positive such that the regulator would always wish to implement $e_2 > 0$ for all β, even in the absence of the liability and commercial incentives[9]. We therefore have six incentive constraints ensuring that each firm should both truthfully announce its type and exerts some level of meat hygiene controls:

$$U(\underline{\beta}, \underline{\beta}, 1) \geq U(\underline{\beta}, \overline{\beta}, 1) \quad (6)$$

$$U(\underline{\beta}, \underline{\beta}, 1) \geq U(\underline{\beta}, \underline{\beta}, 0) \quad (7)$$

$$U(\underline{\beta}, \underline{\beta}, 1) \geq U(\overline{\beta}, \underline{\beta}, 0) \quad (8)$$

$$U(\overline{\beta}\,\overline{\beta}, 1) \geq U(\underline{\beta}, \overline{\beta}, 1) \quad (9)$$

$$U(\overline{\beta}, \overline{\beta}, 1) \geq U(\overline{\beta}, \overline{\beta}, 0) \quad (10)$$

$$U(\overline{\beta}, \overline{\beta}, 1) \geq U(\overline{\beta}, \underline{\beta}, 0) \quad (11)$$

[7] Although it is costly for the regulator to verify the safety, we implicitly assume that some meat-borne disease incidents are reported when detected and can be linked to a firm through traceability records.

[8] 21% and 22% of approximately 500 deaths caused by foodborne disease in 2008 in England and Wales are attributed to Campylobacter and Salmonella respectively, see FOOD STANDARDS AGENCY 2010. Annual Report of the Chief Scientist 2009/10.

[9] Regulator has legal powers to shutdown any firm found to have systemic failures in its food safety controls; therefore, on average, firms will always exert some level of effort to control hygiene.

We also need to impose two participation constraints:

$$U(\underline{\beta},\underline{\beta},1) \geq 0 \quad (12)$$

$$U(\overline{\beta}\,\overline{\beta},1) \geq 0 \quad (13)$$

As proofed in Appendix A, there are only two binding incentive constraints; namely (6) and (13), which are the incentive constraint of the efficient type and the participation constraint of the inefficient type respectively.

Denoting $U(\beta) = U(\beta,\beta,e_2)$, and considering that $e_2 > 0$ is always preferred; the regulator maximizes the expected social welfare function under the remaining four constraints as following:

$$v[S-(1-\pi)(\underline{e}_2)E-(1+\lambda)\left(\underline{\beta}-\underline{e}_1+\psi(\underline{e}_1+\underline{e}_2)\right)-\lambda U(\underline{\beta})+(1\text{-}v)[S-(1-\pi)(\underline{e}_2)E-(1+\lambda)(\overline{\beta}-\overline{e}_1+\psi(\overline{e}_1+\overline{e}_2))-\lambda U(\overline{\beta}) \quad (14)$$

Optimisation of the above equation yields two sets of results:

$$\psi'(\underline{e}_1+\underline{e}_2)=0 \quad (15')$$

$$\psi'(\overline{e}_1+\overline{e}_2) = 1\text{-}\frac{1}{1+\lambda}\ \frac{v}{1-v}\phi'(\overline{e}_1+1), \text{ where } e_2 = 1 \quad (15'')$$

$$\psi'(\underline{e}_1+\underline{e}_2)=0 \quad (16')$$

$$\psi'(\overline{e}_1+\overline{e}_2) = 1\text{-}\frac{1}{1+\lambda}\ \frac{v}{1-v}\phi'(\overline{e}_1), \text{ where } e_2 = 0 \quad (16'')$$

Where $\phi'(m) = \psi(m) - \psi(m-\Delta\beta)$ and m is the volume of meat produced by a firm.

Therefore $U(\overline{\beta}\,\overline{\beta},1) = 0$, and $\phi'(\overline{e}_1) < U\left(\underline{\beta},\underline{\beta},1\right) < \phi'(\overline{e}_1+1)$, whereas the regulator induces hygiene effort as long as the expected gain from meat safety controls exceeds its social cost or $\pi(0) - \pi(1) > 1 + \lambda$.

Our analysis suggests that an optimal MB strategy under incomplete information entails:

(i) A trade-off between efficiency and safety as characterized by equations (15) and (16). This suggests that the regulator may be forced to pay certain a rent over and above the true cost of delegated tasks, in exchange of a greater meat safety which is otherwise costly to verify under incomplete information.

(ii) A rent given up to type $\underline{\beta}$ is greater than $\phi'(\overline{e}_1)$ but lower than $\phi'(\overline{e}_1+1)$, whilst there is no rent for type $\overline{\beta}$. Given that the production scale of a firm determines its operational efficiency, this finding suggests that the larger and technically better resourced larger firms may enjoy greater economic rents than the smaller firms.

(iii) A penalty when meat-borne disease incidents are reported to induce ex post greater hygiene care. This suggests the regulator can retrospectively use penalty regime to punish the firms found to be under complying following an approval for MB regulation, providing a traceability system exists to link reported incidents of disease to a firm.

We next specify an econometric panel model to empirically test these theoretical propositions.

4. Econometric model

As mentioned above, the EU meat hygiene legislation permits poultry abattoirs with an established HACCP system and appropriate level of staff training to self-enforce the hygiene rules. As such, the UK poultry sector is currently governed by two distinct enforcement approaches: a MB regime for firms able to qualifying for approval and a mandatory regime that relies on public inspectors for firms who are either unable to qualify approval or voluntarily opt out of MB regime. In order to test the predictions of the theoretical model, we focus on the subsector governed by MB and compare their efficiency in performing the delegated tasks, based on the estimates of the respective cost-efficiency β_1. Given that the magnitude of the information rent appropriated by an efficient firm is a function of its volume of production, m, we use the poultry firm's annual throughput as a proxy indicator of its type – that is to say is ability to strategically use its economy of scale to extract rents.

This approach is justifiable on two grounds. First, as discussed above, it is widely recognised in the literature on economics of food safety that small firms generally lack technical know-how and resources necessary to design and implement effective food safety management systems. Thus, it reasonable to assume they are less likely to qualify for approval and/or voluntarily opt in for MB regulation compared the medium and large firms. Second, a review of UK delivery models for EU hygiene controls in fresh meat sectors found that 75% of the larger and medium abattoirs, as opposed to only 25% of small plants, used PIAs in 2007 to self-enforce rules (Food Standards Agency, 2007). This review used the annual throughput as a cut off to distinguish medium/large (processing >287000 birds) and smaller (<287000 birds). The eight largest plants alone accounted for almost 50% of the UK production, indicating that the medium and larger firms in aggregate may also account for larger proportion of the reported disease if under-performing the delegated hygiene tasks.

On that basis, for each of the two groups of MB regulated poultry firms, we specify a regulatory cost function model as follows:

$$C_{it} = \beta_0 + \beta_1 x_{it} + \beta_2 y_{it} + \beta_3 z_{it} + \beta_4 d_t + \beta_5 d_t x_{it} + \beta_6 d_t y_{it} + \beta_7 d_t z_{it} + \varepsilon_{it} \qquad (17)$$

C is a total annual inspection cost incurred by the regulator to enforce the official controls at a particular abattoir. This is a social cost comprising two components: a sum of timesheet-based[10] cost for all official inspectors (i.e. public veterinarians and meat inspectors) and the compensation for the delegated tasks performed by for firm's own PIAs. Subscript *i* is an index for an abattoir with certain annual throughput and *t* is for time (in years). β_0 is an intercept for firm-specific characteristics which do not change in time, whereas β_1 is a coefficient of variable **x** which represents annually reimbursed cost per each unit of output produced by a firm (OUTP).

y is the partially recovered annual fee charges to a firm for inspections carried out by official inspectors. **z** is total number of enforcement actions taken against it for any

[10] A full description of how this cost and other variables are calculated is provided in section 5, data.

observed breaches of food hygiene rules in a particular year. ε_{it} is an idiosyncratic error term which changes over time and across the two groups of abattoirs as described below.

d is a dummy variable for the cut off annual output, with d=1 for a medium/large and d=0 for small abattoirs. The remaining three terms in the equation are interaction terms for the dummy and the three variables in the model. Given that the dummy is time-variant, the model specified allows for the coefficients on (effect of) the intercepts and variables **x, y** and **z** to vary across the two groups of firms. We expect that both β_1 and β_2 to increase with the total inspection cost as both the PIA compensation and partial charges add to the total cost of inspections, whereas the sign for β_3 is expected to be negative as increases in number of enforcement actions taken against a firm in year would reduce enforcement activities and thus the social cost in the following year.

In this setting, a fixed-effects estimator is appropriate to control estimates for any unobserved heterogeneity among firms operating in the two groups of MB regulated firms and henceforth yields unbiased coefficients across firms of different sizes (Greene, 2008, Wooldridge, 2002). An additional advantage of this estimator is that it yields consistent estimates even if regressors are partially correlated with the error term, ε_{it} (Baltagi, 2008), providing that this correlation is due to the firm-specific characteristics (Wooldridge, 2002). The error term can be decomposed in this case:

$$\varepsilon_{it} = v_{it} + u_i, \qquad (18)$$

Where v_{it} is a time-variant component assumed to be independent and identically distributed with mean zero and variance σ_v^2. u_i is instead a time-constant component associated the firm-specific characteristics. Baltagi et al. (2009) and Rajan and Zingales (2003) used similar empirical models to study cross-country differences in, and the time variation of, financial development over a number of years. Given that in our case d_t encompasses the unobserved heterogeneity among the firms of different sizes in time, the interaction term between per unit cost for PIAs and the dummy for firm's size is expected to shed light on the difference in the efficiency of the MB regime across the two subsectors – for example, differences in their managerial practices that underlie observed difference in the way they deploy their PIAs and/or use the chargeable official inspection. At the margin, the total effect of increasing per unit PIA cost can be calculated by examining the partial derivatives of total inspection cost with respect to the per unit cost:

$$\frac{\partial C_{it}}{\partial x_{it}} = \beta_1 + \beta_5 x_{it} \qquad (19)$$

5. Data

We use an anonymised data extracted from MHS' official records for UK poultry abattoirs inspections between 2001 and 2008. This data include records of time and throughput-based charges, PIA compensation costs and enforcement activities for each inspected firm. To calculate the total annual cost of the inspections ($\mathbf{C_{it}}$) we have added the annual time-sheet and PIA cost. The timesheet-based costs account for all inspection costs for inspection carried by official veterinarians and meat inspectors in each abattoir. In most cases, the time-based

charges are higher than those accounted on throughput basis and firms are allowed to pay their annual charges on throughput basis if the latter is lower than the time-based charges. Thus, the variable $\mathbf{y_{it}}$ is the lower of the two fee categories – an arrangement which is likely to give advantage the large and medium plants with higher throughput and faster processes. The summary statistics in Table 1 show that at least one of the smallest abattoirs paid no statutory charges although operational, suggesting that the inspections for some of the small (possibly marginal remote rural) plants were fully subsidised.

PIA costs ($\mathbf{x_{it}}$), is accounted separately as the proportion of the salaries (including overtime payments, employers' pension and National Insurance contributions) that operators pay to their PIAs for the time they spend carrying out the delegated official controls. An additional 25% of that sum is added as a contribution towards plant overheads. The summary statistics show that there are considerable variability in the per unit PIA costs, ranging from £0.005 to £8 with an average of £0.14 per poultry bird processed. The difference in the per unit PIAs cost (β_5) for the two groups of firms would in particular reveal whether or not the large and medium firms are able to appropriate rents through redeployment of effort (ψ) away from hygiene controls to, for example, standard production activities. In such eventuality, we expect the smaller firms to simultaneously have a smaller increases in the PIA cost ($\beta_1 + \beta_5$) and greater increases in partial charges ($\beta_2 + \beta_6$) than the medium/large firm. Note that this group (d=0) is excluded from regression.

Regarding the enforcement, five types of different actions are taken against firms found to breach the rules. In increasing order of gravity of breaches, the actions include verbal warning, written warning, minded to notice (Scotland only); improvement notice and recommendation for prosecution (Meat Hygiene Service, 2008). The number of enforcement is thus an indicator of level of under-compliance as firms with a poor food safety capability (e_1) and/or exerting lower PIA effort (e_2) are likely to have higher number of enforcement actions taken against them.

Table 1: Descriptive statistics

Variable	Description	Obser.	Mean	Min	Max
C	Total inspection cost(£)	485	143409.1	1373.07	938417.9
X	PIA cost per unit of output(£)	484	0.1362027	0.000055	8.044555
Z	Number of enforcement actions	478	10.56695	0	164
Y	Partially recovered costs(£)	485	58598.7	0	588922.9
PIAC	Total cost of PIAs(£)	485	51292.16	210.4	354040.9
OUTP	Annual Output	484	8754569	520	8.68×10^7

6. Results

We run fixed-effects regression to test the null hypothesis that the intercepts and individual pairs of the slopes for the two groups of abattoirs are equal – i.e. there is no difference in the intercepts and coefficients. The results reported in Table 2 show that the null hypothesis is strongly rejected for the fixed effects intercept and the coefficients for both unit PIA cost and partial charges. The interaction term for PIA cost is also highly significant, whereas the interaction term for the partial charges is highly insignificant.

The results together suggest that there are significant inherent differences in the way the two groups of firms deployed their PIAs and used official inspectors which they partially paid for. The difference between the slopes for PIAs cost of the two groups of firm (β_5) is substantial, suggesting that the medium/large firms receive considerably more compensations per unit of output than the small firms. Note that all regressors are rescaled up to the dependent variable to facilitate comparison; therefore in absolute terms, the difference is 0.0069 pence per unit of output. Although this figure appears small, for the largest firm in the data (processing $8.68x10^7$ birds) the aggregate value amounts to approx. £4000 per year.

In contrast, the medium and large firm on average paid 0.013 pence per each poultry carcase inspected by official inspectors, compared to 0.019 paid by the small firms. This difference (0.0058 pence per carcase) amounts to £503, 440 efficiency savings for the largest firm compared to average small firm.

Table 2: Results of fixed-effects model

Total cost of inspections=dependent variable

Independent Variable		**Coefficient**	**S.E**
Fixed effects intecept	β_0	64435.61*****	8100.854
Per unit cost	β_1	0.6967*****	0.1701
Partial charges	β_2	0.1342 *****	0.0071
Enforcement	β_3	-3.557	11.3417
Dummy intercept	β_4	-18922.34	19880.3
$d * x$	β_5	-0.6905*****	0.1703
$d * y$	β_6	0.0582	0.5320
$d * z$	β_7	2.2904	35.3763

*****Significant at 99% confidence level

Finally, the slope for enforcement (β_3) has the expected sign but is highly insignificant

7. Discussion

In line with the predictions of the theoretical model, overall the results appear to show that the existing throughput-based charges and PIA compensation scheme have favoured the larger UK poultry plants which have benefited from the greater scale of their operations. The medium and larger meat firms appear to have minimised their overall compliance costs by taking advantage of PIA compensation scheme under the MB regulation due to ineffective approval process and a weak veterinary supervision prescribed by the existing EU law. In this case, the moral hazards problem related to the delegated official tasks performed under incomplete information and compensation has hardened the proceeding adverse selection problem entailed by the proceeding approval process. Consequently, the dual incentive problems together have led to a significant loss of regulatory efficiency. This appear to have materialised through inflated opportunity cost of PIAs effort for the delegated tasks such that the large and medium firms used their greater economy of scale to minimise throughput

charges by mimicking the operationally less-efficient smaller ones whilst at the same time over-claiming PIA costs (Laffont and Martimort, 2002, Laffont and Tirole, 1993).

These findings suggest that the current EU legislation is not rigorous enough to commit firms to social goal of safe meat supply. Evidence linking poor governance of the EU inspection regime and under-compliance in the poultry sector corroborates the findings of the study. Both UK and EU food safety regulatory agencies have recently recognised in major reports that the regime does not provide strong incentives for hygiene controls at abattoir level and as such is unable to prevent contaminated meat entering the food chain (Food Standards Agency, 2008, EFSA, 2012). In this regard, this study makes tangible theoretical and empirical contributions to the literature in this field by systematically the linking weak incentives for compliance to the underperformed delegated auxiliary tasks.

8. Conclusions

Analysis shows that the MB approach has been less efficient in larger firms than the smaller firm. As predicted by the principle-agent model, the larger poultry plants appropriated sizeable economic rents over the eight year period covered by the data. Therefore, the incentive incompatibility between the social goal of safe meat supply at minimal social cost and the poultry firms' minimising objective has led to suboptimal enforcement. As such the MB regime has been incapable of improving public health – a finding that is supported by the reported high disease associated with poultry consumption over the years. This is not surprising as this group of firm process most of poultry meat consumed in the UK.

Two broader conclusions can be drawn from this analysis. First, under a MB approach, food safety is largely an outcome of the strategic firm behaviour and the effectiveness of official oversight of the delegated official tasks. Therefore, without a well crafted regulatory incentive mechanism capable of committing firms to social goals of safe meat supply, the MB regulation is likely to be sub-optimal.

Second, the analysis shows that flexile regulatory strategies, such as MB approaches, may not necessarily deliver better outcomes than the traditional prescriptive regulation they intended to improve upon. In particular, the flexibility afforded to regulated firms through self-regulation may not translate into regulatory efficiency gains where the outcome cannot be verified easily – typically where the information on the outcome is imperfect and it is costly to ascertain it. Thus, a key prerequisite for effective implementation of this form of regulation is to ensure that firms possess not only sufficient administrative capacity and resources for approval for flexible regulation, but also have appropriate incentives to comply with rules.

As highlighted by the principle-agent model, a performance standard coupled with a penalty scheme – for example, a PIA compensation contingent upon third party accredited microbial testing may be necessary to combine it with the current regime, so that the approval process and subsequent veterinary supervision can commit firm to the desired course of action. This approach to enforcement may allow verifiably compliant firms to earn greater recognition, whilst the focus of public inspections is directed toward underperforming firms.

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