The limits of food safety testing: A case study of *Escherichia coli* testing of beef trim

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**A B S T R A C T**

Beef trim, the primary component of ground beef, is tested by both the Food Safety and Inspection Service (FSIS) and meat packers for *Escherichia coli* O157:H7 under a zero tolerance standard. We compare and contrast the process control and filtering roles of this testing on costs and food safety outcomes. Both of these roles of testing have been alternatively emphasized in recent legislative proposals and policy statements on beef trim testing. In the process control role, test design — including the decisions to increase sample sizes, re-test lots, and change tolerance thresholds — only affects the cost of implementing a targeted food safety standard, but does not directly affect health outcomes. In contrast, in the filtering role, test design influences the likelihood of errors and directly affects health outcomes. Neither role eliminates all risk from this pathogen. More broadly, we discuss the incentives food producers face to increase their frequency of testing and improve food safety processes in response to positive test findings as the process control role emphasizes.

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1. Introduction

There are two broad roles of testing a product for a food safety risk: process control and filtering. In the United States, these two roles of testing are used in different current and proposed regulations and applications. In the *process control* role, testing measures the effectiveness of a plant’s production process and provides information for adjusting the process following a failed test. For instance, the U.S. Food and Drug Administration (FDA) tests food imports for adulterants relatively infrequently and a failed FDA test often leads to disruptive, increased future testing or placement on an import alert, thereby incentivizing importers to undertake additional food safety measures. In the *filtering* role, testing intercepts products of concern, such as adulterated food that may sicken consumers if ingested. Another example is that the U.S. Department of Agriculture’s Animal and Plant Health Inspection Service (USDA/APHIS) inspects most fresh agricultural imports for potentially invasive quarantine pests. In these cases, a failed test may create only a relatively small cost to treat or recondition the commodity and have little effect on importer behavior.

We extend the literature by contrasting these two roles of testing through a case study on the testing of beef trim for...
Escherichia coli O157:H7. This paper contributes to the literature by presenting the dichotomy on how a change in the test design (e.g., increased testing) affects testing costs, incentives to packing plants to adopt additional food safety investments, and public health outcomes differently, through its roles as a process control or a filter. As we shall see later in this article, this information is important for policymaking.

The characteristics of this pathogen make it a particularly severe food safety hazard. As part of the Federal Meat Inspection Act (FMIA), the USDA’s Food Safety and Inspection Service (USDA’s FSIS) regularly tests beef trim (i.e., the primary component of ground beef) for E. coli O157:H7 to help ensure that the production process outlined in the packing plant’s Hazard Analysis and Critical Control Points (HACCP) plan is under control. Using the FSIS test protocol, meat packers may also voluntarily test beef trim to filter out adulterated products, which in turn helps limit their liability exposure, reduce recall costs, and meet customer requirements. In either case, a lot that tests positive for the pathogen may not be sold to consumers unless it undergoes an FSIS-approved process, typically cooking, that mitigates the food safety risk.

Because no level of E. coli O157:H7 is permissible in beef trim, testing constitutes a “zero tolerance” standard. However, passing this test does not imply that beef trim is entirely free of pathogens because:

1. The test is not necessarily free of errors (e.g., testing sometimes fails to detect the pathogen when it is present in the sample).
2. The test’s sample may not contain E. coli O157:H7 even when the lot is contaminated, or
3. Other pathogens may be present for which the test is not designed to detect.

While the first concern is primarily technical, the second concern is addressed by recent proposals that would increase sample sizes. The third concern is addressed, in part, by the recent classification of additional six Shiga toxin producing E. coli (STECs) serotypes as adulterants. In recent years, legislative proposals in the United States, such as the proposed 2010 E. coli Traceability and Eradication Act, would have made testing mandatory and required packing plants and processors to increase the size of tests, reducing the likelihood of testing errors. These recent proposals and the new classification of adulterants reflect the current and heightened attention paid to this issue by the scientific community and policymakers in the United States. This issue is also relevant to other developed countries with similar food safety regulations and approaches by packing plants as well to countries where beef is important in national consumption (e.g., Canada).

As background, we first describe E. coli O157:H7 and its public health consequences, the avenues by which beef trim can become contaminated with this pathogen during processing, the beef trim testing process, and the incentives faced by producers to test their product regularly. In this case study, we summarize how both the process control and filtering roles of testing have been the focus of economic inquiry and public policy concern and we highlight the most relevant literature on the role of pathogen testing in the meat industry.

2. The concern over E. coli O157:H7 and its presence in beef

The bacterium E. coli, abbreviated E. coli, is ubiquitous but only specific serotypes of the bacteria are harmful to humans. The serotype E. coli O157:H7 (so named because it carries the O157 and H7 antibodies) has been the predominant focus of public policy attention since it was linked to the 1993 Jack-in-the-Box outbreak, which caused over 300 illness and 4 deaths and marked a watershed in spurring food safety legislation in the United States (Loader & Hobbs, 1999). Since 1994 when FSIS declared it an adulterant in beef trim, E. coli O157:H7 has been a primary pathogen targeted in FSIS’ testing of beef trim for human consumption (Food Safety and Inspection Service, 2011a, 2011b). This designation of E. coli O157:H7 as an adulterant only applies to non-intact beef cuts, including beef trim later made into ground beef, but not to whole cuts which include steaks or roasts (Alvares, Lim, & Green, 2008). This designation provides FSIS with the legal authority to seize products in commerce shown to contain E. coli O157:H7 and later led to mandated food safety and quality control measures, such as FSIS testing and the requirement that all Federally-inspected meat slaughter and processing plants maintain HACCP plans.

More recently in September 2011, FSIS announced that six additional serotypes of Shiga toxin producing E. coli (STECs) (i.e., strains carrying the anti-bodies O26, O45, O103, O111, O121, and O145) were also adulterants and gave plants notice that FSIS testing and plant HACCP plans needed to address for the possible presence of these pathogens as well (Food Safety and Inspection Service, 2011a, 2011b). The focus of the remainder of this paper is primarily on E. coli O157:H7.

The Shiga toxin produced by E. coli O157:H7 can cause acute and chronic illness when it is ingested in contaminated food or spread by other routes, such as person-to-person contact. Beef is a common food vehicle for this pathogen. The U.S. Centers for Disease Control and Prevention estimates that 63,153 domestically-acquired foodborne illnesses are associated with E. coli O157:H7 each year (Mead et al., 1999, Scallan et al., 2011) which imposes an estimated $219.9 million in annual health costs according to the USDA’s Economic Research Service (Economic Research Service, 2010; Frenzen, Drake, Angulo, & The Emerging Infections Program Foodnet Working Group, 2005; Scallan et al., 2011). Because E. coli O157:H7 lives harmlessly in the gastrointestinal tracts of cattle and can easily be transferred to the carcass during slaughter, it is difficult to completely eliminate it from beef trim (Naugle, Holt, Levine, & Eckel, 2005). Box 1 provides greater detail on E. coli O157:H7 in the slaughter process.

Following fabrication, FSIS or packers may test beef trim for E. coli O157:H7 before it is used for grinding. If trim tests positive or, as a matter of semantics, non-negative, then FSIS requires it to be treated or re-conditioned with a kill step to mitigate the pathogen risk so that the meat can be sold for human consumption. Given the lack of consumer acceptance of irradiation, contaminated beef trim is typically sold to a facility that cooks and sells it for uses such as pizza topping or sausage. If FSIS confirms that the product is adulterated with E. coli O157:H7, it will investigate what actions on the part of the packer may have led to the adulteration so that the production process can be brought back under control. It will also perform more frequent follow-up tests following a positive test. If the process is judged to not be in control, FSIS can request changes to the packer’s HACCP plan or withdraw inspection services, which effectively shuts down production and no further beef trim can be produced and sold.

3. Testing for E. coli O157:H7

The frequency that FSIS tests of beef trim for E. coli O157:H7 depends on the plant’s output.¹ For very large plants producing more than 250,000 lbs daily, FSIS guidelines require more than one
While a serious threat to human health, *Escherichia coli* O157:H7 does not affect the health of beef cattle or create any visible symptoms. Living and reproducing in the animal’s alimentary tract, the pathogen is ubiquitous in cattle, although individual animals differ in terms of concentrations of the pathogen shed in fecal matter. These shed rates are seasonal, being highest in late summer months, and episodic, reaching very high concentration levels in some cattle (i.e., super-shedders) (Arthur, Bosilevac, Nou, & Koohmaraie, 2005; Arthur et al., 2010, Matthews et al., 2006). *E. coli* O157:H7 survives most stages of the beef supply chain, including freezing, and it can grow and multiply slowly at temperatures as low as 44°F (Food and Drug Administration, 1994). However, the pathogen is easily killed when cooked to at least 160°F.

Beef slaughter and packing has been divided into distinct steps which are, sequentially: loading and stunning, de-hiding, first stage decontamination, evisceration, second stage decontamination, chilling and fabrication. De-hiding and evisceration are the stages of slaughter with the greatest likelihood of transferring the *E. coli* O157:H7 pathogen to meat, described in detail by FSIS (Food Safety and Inspection Service, 2010a, 2010b, 2010c; Koohmaraie et al., 2007, Koohmaraie et al., 2005). During de-hiding, the pathogen can be transmitted to the carcass from hides that have been fouled with mud and feces. During evisceration, the gastrointestinal tract of the animal may become perforated, exposing the carcass to the contents of the colon. Carcass contamination is particularly problematic for beef trim as this material is often collected from exterior sections of the carcass, including the fat cover near the hide, rather than from whole cuts.

Preventative measures and decontamination steps inhibit the growth of microorganisms which, along with testing and other actions, create a hurdle process that enhances the effect of individual measures (McMeekin, Olley, Ratkowsky, & Ross, 2002). Packers can invest in equipment that pasteurizes the carcass (e.g., with steam or hot water) or removes spot contamination (e.g., steam vacuuming in the de-hiding stage). They can also wash carcasses with organic acid during evisceration. Equipment can de-hide the animal mechanically in a less hazardous manner than removal of the hide, or if instead equipment is available that creates negative pressure around the hide so that the pathogen is not aerosolized during de-hiding and spread to other parts of the carcass. Additionally, packers can provide instruction and incentives for workers to maintain best practices. These include: regular sanitation of knives, gloves, uniforms, handling equipment, and work areas; proper instruction on how to de-hide and eviscerate animals; maintenance of proper temperature controls in plants; and control steps in addressing contamination when it occurs. Regular testing of beef trim for *E. coli* O157:H7 also reduces the potential for food safety risks.

Although FSIS recommends five practices to reduce *E. coli* O157:H7 prevalence in cattle herds, these practices have not been explicitly linked to contamination and food safety outcomes (Arthur et al., 2009; Food Safety and Inspection Service, 2010a, 2010b, 2010c; Koohmaraie et al., 2007; Loneragan & Brashears, 2005; Sargeant, Amezcue, Rajic, & Waddell, 2007). These practices include maintaining clean water and feed, keeping living environments well-drained, separating calves and heifers in housing or reducing animal density, and maintaining biosecurity to exclude wildlife that might be carriers of this and other pathogens. Ideally, better cattle practices would lower *E. coli* O157:H7 prevalence on the animals that comprise the source material of beef trim. However, packers control animals for far too short of a period (typically less than a day) to affect pathogen loads through feeding or housing practices.

Importantly, none of the investments or actions previously discussed are considered “kill” steps — actions that, unto themselves, entirely mitigate the food safety risk. Rather, these sequential interventions are designed to reduce the pathogen to low or imperceptible levels so that consumer cooking mitigates the remaining hazard. Packer level kill steps include cooking or irradiating the final product. In the case of Lean Finely Textured Beef (LFTB), treatment with gaseous ammonium hydroxide reduces, but does not eliminate, *E. coli* O157:H7 if it is present in the beef trim (Greene, 2012). Because irradiation is controversial and can reduce consumer demand, it has not been adopted widely (Ferrier, 2010; Hayes, Fox, & Shogren, 2002). Alternatively, cooking limits the range of potential end uses and the marketability of the meat. And, importantly, cook-only beef trim sells at a price discount to fresh beef trim. 

**Box 1**

*E. coli* O157:H7 in the slaughter process.

- **While a serious threat to human health, *Escherichia coli* O157:H7 does not affect the health of beef cattle or create any visible symptoms. Living and reproducing in the animal’s alimentary tract, the pathogen is ubiquitous in cattle, although individual animals differ in terms of concentrations of the pathogen shed in fecal matter. These shed rates are seasonal, being highest in late summer months, and episodic, reaching very high concentration levels in some cattle (i.e., super-shedders) (Arthur, Bosilevac, Nou, & Koohmaraie, 2005; Arthur et al., 2010, Matthews et al., 2006). *E. coli* O157:H7 survives most stages of the beef supply chain, including freezing, and it can grow and multiply slowly at temperatures as low as 44°F (Food and Drug Administration, 1994). However, the pathogen is easily killed when cooked to at least 160 °F.**

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probability of drawing, and therefore detecting, a contaminated piece rises. Ironically, if the rate of contamination is less than 5% (but still positive), the probability that sampling fails to detect the pathogen rises. Critics of the n-60 protocol argue that the protocol samples too little material to detect contamination (Healy, 2009; Office of Inspector General, 2011; Safe Tables Our Priority, 2008).

The testing method (i.e., specific lab test or technology) used by packers, however, filters or screens for E. coli O157:H7 but is not intended to provide confirmatory evidence of its presence. Confirming this is expensive and firms are not legally required to do it. And, without confirmation of the pathogen’s presence, producers may have limited incentives to address food safety concerns in the production process. Subsequently, firms may simply re-route screened positive beef trim to cook only uses. In this case, testing improves food safety predominately by filtering out adulterated product, rather than through changes in the production practices.

In contrast to the concern that too-small sample sizes fail to detect contamination when it is present, alternative FSIS-validated testing methods vary in their likelihood of having the opposite error — to detect contamination when it is not present. In general, quicker less expensive methods, such as the lateral Flow (LF) method are more likely to have a false positive than longer more expensive methods, such as the Polymerase Chain Reaction (PCR) method (see Ferrier & Buzby, 2013). FSIS recognizes that the PCR test is less prone to error than the LF test and permits product that test positive for E. coli O157:H7 in an LF test to be sold as fresh if it subsequently passes a PCR test. From a regulatory standpoint, however, both the LF and the PCR tests are screening tests (Food Safety and Inspection Service, 2010a, 2010b, 2010c) where a still more lengthy and rigorous test is necessary to isolate and confirm the presence of the pathogen (Food Safety and Inspection Service, 2010a, 2010b, 2010c). When FSIS itself conducts tests of beef trim lots, each initial positive screening test is followed by a confirmatory test. Packers, however, may choose to act differently on the results of a positive screening test and not follow them up with confirmatory tests. Because screening tests do not conclusively prove that E. coli O157:H7 is present, a positive screen test does not obligate packers to correct potential flaws in the production process under HACCP as there is no direct evidence that E. coli O157:H7 is present.

The specific costs of testing are difficult to verify. Based on communications with firms offering testing services and industry representation, Ferrier and Buzby (2013) estimate that physical costs to sampling and testing at the n-60 level in an LF test is $30 per test and that the less frequently performed PCR test is $60. Embedded in any testing regime are the additional costs of interrupting the supply chain, maintaining traceability of lots, and sorting and refrigerating lots while waiting for test results. This last process is often referred to as “test and hold” although the actual “holding” of lots on site is not actually necessary. Instead, packers must simply maintain control of the lot and delay its final processing, while still shipping it to a distant destination. Lots that test positive in screening tests will be held even longer if confirmatory tests are performed.

The current U.S. regulatory structure supports the homogenization of testing practices across packers. FSIS generally accepts the packer’s test as evidence that a production process is in control if the testing and sampling method is as rigorous as the FSIS method. If a lot of beef trim tests positive and is confirmed to contain E. coli O157:H7, other lots produced in the production run may be implicated by the test and also considered ‘adulterated’. Packers may test trim regularly to limit the amount of volume they could potentially be forced to sell on the lower-priced, cook-only market. Similarly, if E. coli O157:H7 is found in ground beef, other ground beef produced from the same production run may also be considered adulterated by FSIS. Again, regular testing limits the size of the potential recall and associated economic losses.

4. The dual role of testing: process control and filtering

This section presents the key literature on the role of pathogen testing in the meat industry. It also extends the literature by comparing and contrasting the two roles of testing beef trim for E. coli O157:H7.

4.1. The process control role of testing

Since 2000, FSIS has required federally-inspected meat and poultry slaughter and processing plants to have HACCP plans to ensure that a plant’s food safety process is in control (Unnevehr & Jensen, 1999). Typically, these HACCP plans include both preventative measures to reduce the occurrence of pathogens in finished products and testing of intermediate and final products. Within these plans, testing is intended to determine whether these food safety processes are effective, rather than to filter or “catch” contaminated products (Ollinger et al., 2011). As previously mentioned, FSIS expanded testing of beef trim to the six non-O157 STECs and in a 2011 Federal Register posting, reiterated the text of a 1994 speech by then-FSIS Administrator Michael R. Taylor that:

“To clarify an important legal point, we consider raw ground beef that is contaminated with E. coli O157:H7 to be adulterated within the meaning of the [Federal Meat Inspection Act]. We are prepared to use the Act’s enforcement tools, as necessary, to exclude adulterated product from commerce...We plan to conduct targeted sampling and testing of raw ground beef at plants and in the marketplace for possible contamination. We know that the ultimate solution to the (E. coli) O157:H7 problem lies not in comprehensive end-product testing but rather in the development and implementation of science-based prevention controls, with product testing to verify process controls.”

The economic literature provides some discussion of the process control role of testing. In particular, Ollinger and Moore (2009) and Starbird (2005) consider how testing influences process control and the provision of food safety in the beef industry. Ollinger et al. (2011) argue that the potential for recalls and failed safety tests creates reputation effects. Moreover, a significant portion of the firm’s value is intangible and subject to loss if the firm becomes associated with negative food safety events. For example, Foodmaker Inc. [the parent company of Jack in the Box Inc.] lost an estimated $160 million in the first 18 months after the 1993 E. coli O157:H7 outbreak (Roberts, Morales, Lin, Caswell, & Hooker, 1997). A processor whose product is recalled or implicated in a food safety lawsuit may discontinue all business with the packer that supplied the trim or make future purchases contingent upon the packer undertaking additional food safety investments. Testing outcomes play a similar role in establishing reputation effects, and some processors may request that suppliers of beef trim test all their output. This role of processors making purchases contingent upon food safety investments may be linked to contractual ties or vertical integration ties that bind packers and processors in long-run relationships. This view stands in contrast to popular press accounts of large packers with market power pressuring small processors to
not re-test beef trim before processing, presumably for fear of immediate revenue loss (Moss, 2009).

In general, the beef packing industry is very concentrated, but the scale of the firm can vary dramatically from plant to plant. Large packers can slaughter 12,000 cattle a day on the high-end; small plants may slaughter only a dozen or so animals a week. Table 1 shows how different sized firms undertake food safety investments (based on their quintile distribution of annual output). In this work, Ollinger et al. (2011) develop several index values for food safety measures, ranging from the least rigorous as 0 to the most rigorous as 1, that capture the firms’ food safety investments in critical areas including de-hiding, sanitation, operations, testing, and equipment. For example, a firm can invest in equipment that removes the hide in a way that reduces the chance that it contaminates the carcass.

Ollinger et al. (2011) find that larger firms tend to invest more in measurable food safety equipment, testing, and employee training than smaller firms and offer several explanations. First, larger firms face a larger liability and negative media exposure when a food safety event results in a lawsuit or lost business. This larger downside risk spurs greater food safety investment. Second, scale economies make event results in a lawsuit or lost business. This larger downside risk face a larger liability and negative media exposure when a food safety than smaller

For example, a way that reduces the chance that it contaminates the carcass. For example, a

which increases the cost to the principal of targeting any specific food safety actions in a principal-agent framework. In this approach, the principal may be represented by the processor or the packer while the agent may be represented by the line workers or plant managers where the principal contracts with an agent to exert effort that reduces the probability that a lot is contaminated. For example, agents (i.e., line workers at a packing plant) can clean knives more frequently than others or may make more careful cuts. The principal, however, cannot easily observe whether the agent exerts effort, but only observe the outcomes of food safety tests after the production process occurs. The principal, therefore, makes the agent’s compensation dependent on the outcome of the food safety tests.

Optimally, every production lot should be sampled and tested before leaving the supplier and again before use at the receiver. Results of the testing program should be conveyed back to supplier

provide safety assurance. To the extent that more frequent testing reduces the risk faced by agents, it also lowers the contracting cost to implement a desired food safety objective.

In practical applications, packers (as principals) may find it difficult to efficiently devise contracts that incentivize food safety actions for line workers (as agents) for several reasons. First, the benefit to principals of avoiding a food safety event—in terms of size, costs, duration, or effect on brand reputation—may be unknown. Second, the agent’s cost of effort may be variable (depending on experience), idiosyncratic (depending on the pathogen loads on carcasses), or jointly determined (depending on several links in the supply chain). Determining a compensation rate that provides an incentive for increased food safety effort may be challenging in these circumstances. Third, the distinction between principal and agent may be unclear. Contractual incentives may come from buyers (i.e., processors of beef trim), in which case, packing plant managers may be considered the agents whose effort is their capacity to direct the actions of line workers. Moreover, if processors wish to gain greater control over the production process, they can vertically integrate with the packing process to more directly influence workers’ actions. Hennessy (1996) argues that such vertical linkages remove a portion of the information asymmetry problem that leads firms to underinvest in food quality or safety improvements.

4.2. The filtering role of testing By diverting beef trim to cook-only uses, testing also performs a filtering role that improves food safety. Draft guidelines from the FSIS (2008) express concern that testing is only used for testing and recommend, but do not require, producers to alter production practices based on positive screen tests stating:  

For each positive result, there should be an investigation of its cause. Once a possible cause is identified, then appropriate action should be taken to make corrections and to eliminate the cause. Doing so will bring a steady decline in the percentage of positive results. Feedback of sampling and testing results to the supplier of the source materials should be provided as a matter of good manufacturing practice. Importantly, there should be an affirmative following-up on each and every positive test result with the supplier, whether you produced the trimmings or procured the source materials from another supplier. Without reporting, the sampling and testing program is merely a “test-and-divert” program. Test-and-divert programs will not prevent, eliminate, or reduce to a non-detectable level E. coli O157:H7 in raw beef.

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Firm tendency to undertake food safety investments and testing by plant size.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plant size quintile</td>
<td>All plants</td>
</tr>
<tr>
<td>0–19</td>
<td>20–39</td>
</tr>
<tr>
<td>Output (1,000 pounds of output)</td>
<td>28</td>
</tr>
<tr>
<td>Number of Plants Surveyed</td>
<td>50</td>
</tr>
<tr>
<td>Overall Index (Mean Index)</td>
<td>.32</td>
</tr>
<tr>
<td>Dehiding Index</td>
<td>.43</td>
</tr>
<tr>
<td>Sanitation Index</td>
<td>.55</td>
</tr>
<tr>
<td>Operations Index</td>
<td>.44</td>
</tr>
<tr>
<td>Equipment Index</td>
<td>10</td>
</tr>
<tr>
<td>Testing Index</td>
<td>.05</td>
</tr>
</tbody>
</table>

Note: Mean Index Values range from 0 to 1 where 1 represents the safest value of each index. Source: Ollinger et al. (2011).
in order for the supplier to assess the adequacy of its slaughter and dressing program and the sampling and testing program for trimmings.

Because “n-60” testing already has a zero tolerance threshold, many proposals to increase the rigorousness of testing require some combination of more tests to be performed, more sampling within each test (i.e., increase sample size), and re-testing. The E. Coli Traceability and Eradication Act (2010), if implemented, would have increased testing by: requiring packers to test all lots of beef trim, requiring processors to test all beef trim received (unless they are the same entity as the packers), and mandating regular scientific review of testing standards. The proposed act, however, would also have obligated packers and processors to test beef trim and report the results to the FSIS within a day of learning the results. While both these documents call for more testing, they also encourage packers and processors to undertake process control measures (by reporting positive tests) rather than simply filtering products out of the fresh supply chain.

In practice, the rigor of testing may be increased in a variety of ways. Packers can test all lots or even all combo bins, processors can test lots before grinding, or tests could require larger sample sizes. As previously mentioned, Moss (2009) reports that processors test lots before grinding, or tests could require larger sample sizes.

### Table 2
Comparison of process control and filtering roles in beef trim testing for E. coli O157:H7.

<table>
<thead>
<tr>
<th>Process control role</th>
<th>Filtering roles</th>
</tr>
</thead>
<tbody>
<tr>
<td>Principal determined, depending on the desired food safety objective.</td>
<td>Market determined, depending on recall and liability costs and relative value of products.</td>
</tr>
<tr>
<td>Reduction in other non-O157 pathogen risk because improved process controls likely affects both set of pathogens.</td>
<td>No reduction in other non-O157 pathogens unless the presence of both sets of pathogens is correlated.</td>
</tr>
<tr>
<td>Smaller, a higher frequency of testing only has an effect if the production process is out of control.</td>
<td>Larger, a higher frequency of testing uncovers more contaminated lots.</td>
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<tr>
<td>Indirect, smaller errors only reduce the uncertainty associated with contracting for a food safety investment.</td>
<td>Direct, smaller errors lessen the chance that contaminated trim reaches the market.</td>
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Outside of FSIS testing, firms are not required to test trim themselves. However, if firms do test trim, the magnitude of the financial penalties they face for producing a product that tests positive for E. coli O157:H7 are unclear. Within the principal-agent framework associated with the process control role of testing, a principal creates incentives for workers to expend effort to improve food safety. Within the filtering role of testing, incentives for food safety improvement emerge from market prices where the incentives for improving food safety are likely to be weaker because of the lack of a coordinated relationship between that particular buyer and seller. If a lot is contaminated, packers receive lower prices if the product is sold on the cook-only market or potentially face liability and recall costs and the loss of brand reputation if the product is sold as a fresh product to consumers. If these costs and the markdown on cook-only products are small, however, positive tests may create relatively small incentives for packers to make food safety investments.  

Ferrier and Buzby (2013) estimate the economically optimal sampling rates for E. coli O157:H7 when it acts primarily as a filtering mechanism, rather than a process control mechanism. In their model, testing via sampling improves food safety by diverting contaminated products to be re-conditioned, but does not provide incentives to invest more in food safety improvements. Increasing sampling also increases testing costs. They find that, in most cases, the economically efficient sample size, equating the marginal benefits and costs of further sampling, should be increased above the current level of 60, but not above 120, the level consistent with re-testing. For instance, they use simulations to show that the economically efficient sample size is 94 when a lot weighs one metric ton, a test of 60 samples costs approximately $35, and the contamination rate of lots is 8%. Using a similar method but different assumptions on the modeling of risk, Powell (2013), in contrast, finds that current test size of 60 is efficient. Both works, however, show that when lots are larger and expected contamination rates are high, the optimal sample size is higher and vice versa. Importantly, in the filtering framework, increased testing is oriented towards intercepting lots contaminated at low, but still positive, prevalence rates. “DIRIER” lots where the prevalence of contamination is high (i.e., most sampled pieces of beef trim will contain E. coli O157:H7) are easier to detect with sampling and so less sampling may be needed.

FSIS’ concern that testing is simply used as a filtering process may not be limited to the sampling error problem alone. As a filtering mechanism, testing has a narrow band problem in that it only detects the specific pathogens for which it is testing. While the inclusion of other pathogens within the test reduces this problem, it will also increase the costs of testing, particularly if it increases the likelihood of errors in screening process. As a process control mechanism, testing leads to corrections of the production process which addresses all pathogens simultaneously. If the effect of food safety actions on pathogen risk is correlated across pathogens, then testing for additional pathogens may have relatively little additional effect as a process control but a substantial effect as a filter.

Ollinger (2013) illustrates how filtering may occur in his examination of the testing of beef trim for Salmonella by the National School Lunch Program (NSLP). The NSLP only purchases beef trim from approved facilities and that meet a higher tested, safety standard than for otherwise commercially acceptable beef trim. While hard data is not available, purchases into the program are
assumed to be associated with a price premium as well as greater penalties if a product is found to be contaminated in the test. Importantly, approved producers may forego selling some of their product to the NSLP program. Ollinger finds that lots of beef trim sold to the NSLP are less likely to positive than lots from the un-approved producers. However, lots from these same approved producers that are not sold to the NSLP are more likely to test positive than those of unapproved producers. In this case, producers seem to have private knowledge of the risk of salmonella contamination at the time that they choose marketing outlets. Moreover, the lower risk profile of lots sold to the NSLP program by approved producers is explained in part by the sellers removing lots that they suspect are more likely to be contaminated. Ollinger could not conclude whether the lots of approved producers are, in fact, less risky than those of unapproved producer’s on average (i.e., testing improves process control).

5. Conclusion

In short, we show that test design affects the cost of implementing food safety investments in the process control role, whereas it directly affects health outcomes in the filtering role. Subsequently, we show that by affecting the test error, the level of sampling directly affects health outcomes when testing is used as a filter. While both roles improve consumer health outcomes, they have different implications when testing is associated with error. Within the process control role, errors where tests fail to detect contaminated material primarily increase the cost of incentivizing additional food safety investment and thus only indirectly affect health outcomes. If firms face weak incentives to improve food safety, reduced testing error may have little effect on food safety investment. Within the filtering role, similar errors result in contaminated product reaching consumers, directly affecting health outcomes. Table 2 presents a comparison of process control and filtering roles in beef trim testing for E. coli O157:H7.

Using beef trim as a case study, we examined how testing can improve food safety outcomes, by acting both as process control and filtering mechanism. When acting as a process control, testing may be infrequent but connected to strong incentive to adjust the production process to make it safer. On the other hand, when acting as a filtering mechanism, testing may still be infrequent and associated with weak incentives to improve the process if both recall costs and markdowns on cook-only products are low. We have shown that at different times, current and proposed regulations and policy guidelines have emphasized these alternative roles.

Zero tolerance in testing does not imply a lack of testing error. Increased sampling, however, can lower the probability of an error in testing as recent policy proposals have emphasized. Within a process control framework, increased sampling reduces the cost of implementing a given performance standard and only indirectly affects health outcomes. Within a filtering framework, the effect on health outcomes is direct where increased sampling lowers errors and directly prevents contaminated products from reaching the market. Institutional mechanisms concerning recall costs and liability have led some producers to test all their output using the FSIS sampling protocol. However, without strong incentives, testing outcomes may not impact the production process, even if increased sampling strengthens the role of testing as a filter.

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References


