A COMPARISON OF HUMAN ILLNESS COST ESTIMATES FOR *E. COLI* O157:H7 DISEASE IN THE UNITED STATES AND SCOTLAND

by

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Abstract

This paper explores differences in estimated social costs from foodborne *Escherichia coli* O157:H7 between the United States and Scotland with particular attention paid to methodological issues and categories of illness severity. Depending on the method of valuing premature deaths, estimated medical costs and lost productivity in the United States average $10,000-$21,350/case. The estimated cost from the largest reported Scottish milk-borne outbreak is $34,564/case. Costs per case were higher in Scotland predominately because the Scottish cases did not include patients who did not seek medical attention and because the Scottish cases had a higher percentage of the more costly complication of the disease, hemolytic uremic syndrome (HUS), typical of an outbreak. The U.S. estimates were based on the likely annual incidence of disease predicted by the Centers for Disease Control and Prevention.

Keywords: *Escherichia coli* O157:H7, foodborne disease, economic costs.

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INTRODUCTION

Escherichia coli (*E. coli*) O157:H7 achieved notoriety in the United States with the 1993 outbreak from eating lightly-cooked hamburger which sickened over 700 people and killed four children. In 1997 in Scotland, over 400 people became ill and 20 died from eating contaminated beef and beef products from a local butcher. In the United States, attention by government and public interest groups to this bacterium and its associated disease was particularly strong because children were primarily affected and lifelong kidney failure or death can result. Each year in the United States, *E. coli* O157:H7 is estimated to sicken 20,000-40,000 people and causes 79-158 deaths, of which 80 percent are considered to be from foodborne sources (*i.e.*, 16,000-32,000 cases and 63-126 deaths) (Buzby and Roberts, 1997). With less than one quarter of the U.S. population, England, Wales, and Scotland has about 1,369 illnesses and 13 deaths from foodborne *E. coli* O157:H7 per year (Adak, 1997).

Economists in the United States (U.S.) and United Kingdom (U.K.) have estimated human illness costs associated with foodborne *E. coli* O157:H7 disease. The U.S. outbreak and estimates of foodborne illness costs to society were instrumental in inducing the first improvements in regulations governing U.S. meat and poultry slaughter and processing plants in over 90 years. This paper explores differences in estimated social costs between the United States and Scotland for this foodborne disease with particular attention paid to differences in method and disease severity.

E. COLI O157:H7

Although *E. coli* O157:H7 was isolated by the U.S. Centers for Disease Control and Prevention (CDC) in 1975, it was not identified as a foodborne pathogen until 1982 following outbreaks associated with fast-food hamburgers in Oregon and Michigan. It was first identified in England and Wales in 1982 and each year, with the exception of 1993, the number of reported isolates has increased. Today, illnesses from this pathogen have been reported worldwide.

E. coli O157:H7 causes a wide range of illness severities in humans from mild cases of acute diarrhea to premature death. Acute illness from *E. coli* O157:H7 disease is manifested by abdominal cramps, vomiting, diarrhea (often bloody), and sometimes fever. Although most *E. coli* O157:H7 infections are mild and do not require medical care, *E. coli* O157:H7 infections can result in hemorrhagic colitis (bloody inflammation of the colon). Most patients with *E. coli* O157:H7-induced hemorrhagic colitis recover without developing secondary complications, while others develop hemolytic uremic syndrome (HUS) (Griffin and Tauxe 1991, p. 65). Although less than 5 percent of all *E. coli* O157:H7 disease cases develop HUS, outcomes from HUS are severe. HUS is a life-threatening disease characterized by red blood cell destruction, kidney failure, and neurological complications, such as seizures and strokes (McCarthy 1993, p. 10A; AGA 1995, p. 1923). Those who develop chronic kidney failure may require lifelong dialysis or a kidney transplant. Other neurological complications such as central nervous system deterioration, blindness, or partial paralysis may also result (Merck 1992). Many HUS patients die.

HUS especially strikes children under 5 years of age and the immunocompromised elderly (Griffin *et al.* 1988; Griffin and Tauxe 1991; Martin *et al.* 1990). *E. coli* O157:H7 disease is the leading cause of acute kidney failure and HUS in young children and infants. Tarr *et al.* (1989, p. 585) found that *E. coli* O157:H7 disease is the leading cause of HUS in the Pacific Northwest. Siegler *et al.*'s (1994) results from a 20-year population based study of HUS in children in Utah were consistent with Tarr *et al.* Similarly in the United Kingdom, *E. coli* O157:H7 disease is a major factor for HUS (Fitzpatrick, 1997; Taylor, 1997).

U.S. incidence estimates of annual cases of foodborne *E. coli* O157:H7 disease were developed using best estimates of the actual number of cases. Scottish cost estimates were developed using outbreak data from the largest reported milk-borne outbreak. The U.S. cost-of-illness estimates were updated from Roberts and Marks' (1995) estimates for *E. coli* O157:H7 and the procedure is documented in Buzby *et al.* (1996). The Scottish estimates are documented in Roberts and Upton (1997).

THE COST-OF-ILLNESS METHOD

Malzberg founded the cost-of-illness method in 1950 and Rice codified its empirical application in 1966. The method sums the total costs borne by all individuals afflicted with a given disease or illness. Cost-of-illness studies vary widely in scope, ranging from detailed accounting of a broad-based topic to studies that consider a few cost types for a specific illness in a limited geographical region. In practice, most cost-of-illness studies on foodborne illness focus on medical costs and the indirect costs of lost productivity (*i.e.,* forgone income) to obtain partial estimates of annual costs. In theory, all other social costs borne by individuals should be included. Pain and suffering, lost leisure time, child care costs, travel costs, and averting behavior costs are generally excluded due to lack of reliable measures (Roberts, 1986).

The lower bound on U.S. productivity losses for those who died and for who were unable to return to work was estimated using Landefeld and Seskin's (LS) estimates of the present value of potential future earnings. Landefeld and Seskin offer a hybrid approach which reformulates the human capital (HC) estimates with willingness to pay (WTP) criterion. This approach benefits from the welfare foundation of the WTP method while benefiting from the consistent, understandable, and objective calculations of the HC approach (Landefeld and Seskin). The LS method generates the present value of expected lifetime after-tax income and housekeeping services at a 3% real rate of return, adjusted for an annual 1% increase in labor productivity and a risk aversion premium of 1.6 (based on insurance data). Although, this "human capital" approach does not account for all costs (*e.g.*, lost leisure time, pain and suffering), it has been used as a proxy for the value of a premature death (Buzby et al. 1996; Buzby and Roberts, 1997). Under this approach, the value of a premature death (V) is:

$$V = [\sum_{t=0}^{T} \frac{Y_t}{(1 + r)^t}]\alpha$$

where T = remaining lifetime, t = a particular year, Y_t = after-tax income (labor plus non-labor), r = household's opportunity cost of investing in risk-reducing activities, and α = risk aversion factor. We averaged LS estimates across gender for each age category and updated to 1996 dollars using usual weekly earnings. The U.S. estimates were based on typical four-year-old patients; the value for a 4-year old under this human capital approach is $1,533,000.

The upper bound on U.S. productivity losses for those who died and for who were unable to return to work was estimated using $5 million midpoint from a range of estimates compiled by Viscusi (1993). We refer to this as the "labor market approach" because he compared wage differences in 24 wage-risk studies and found that the extra wages associated with the increased overall hazard of one death from risky jobs are between $3 million and $7 million (in 1990 dollars). Several regulatory agencies use either Viscusi's range of estimates or the $5 million midpoint when analyzing the benefits of proposed public-safety rules. The hedonic-wage approach uses labor market data to estimate consumers' willingness to pay. Workers, often subconsciously, place a value on life and health when they earn higher wages in jobs that incur risks. Typically, employers must offer workers higher wages to induce them to take such a job, as opposed to similar jobs with no such risks.

For the Scottish productivity losses of those who died, we used the U.K. Department of Transport's value of lives lost in railroad accidents, £2.3 million ($3.76 million).[1] The Scottish estimates of lost productivity for those who did not die prematurely because of their illness were based on the actual age distribution of patients, half of whom were under 5-years old. Table 1 highlights other differences in the methodology for the U.S. and Scottish cost studies.

COSTS OF FOODBORNE *E. COLI* O157:H7 IN THE U.S. AND SCOTLAND

Estimated medical costs and lost productivity for the foodborne *E. coli* O157:H7 disease range between $158 million to $315 million each year (in 1996 dollars) when the conservative LS method was used to estimate lost productivity, with an average of roughly $10,000 per case (HUS and non-HUS cases combined). When a less conservative valuation was used ($5 million per statistical life), estimated foodborne *E. coli* O157:H7 disease costs are $343-$681 million, with an average of roughly $21,350 per case.

Although annual cost estimates are not available for the United Kingdom, estimates of the average cost per case were developed using outbreak data from the largest reported milk-

[1] These estimates were based on consumer's willingness to pay to avoid risks of death, pooled over a large number of people.

borne outbreak in Scotland. The average estimated cost from this outbreak is $34,564/case.[2]

The Scottish cost estimates are higher than the incidence-based U.S. cost estimates primarily because the costs in Scotland were based on data from an outbreak which did not include mild cases. Outbreaks typically have a higher percentage of more severe cases than do incidence estimates because the more frequent and milder, sporadic cases are less likely to be reported. A higher percentage of Scottish cases developed HUS as a secondary complication and therefore incurred greater costs (*i.e*., 11 out of 71 Scottish cases (15.5%) were HUS cases as opposed to 800-1,600 HUS cases out of a total 16,000-32,000 U.S. foodborne cases (6.25%). Had an additional 100% of the total cases in the Scottish outbreak (71 cases) been added to the 71 cases to account for the mild cases, as in the U.S. analysis, the percent that developed HUS would be more in line with the U.S. percentage (7.7%).

Several factors also caused the estimates to vary such as differences in the disease reporting systems, standard medical treatment and practice, and economic methodologies used to develop cost estimates. The most striking differences in method are the discount rate and the valuation of premature death which affects both the level and variability of the cost estimates (Table 1).

To better understand the cost differences between countries, Table 2 divides the relevant foodborne *E. coli* O157:H7 disease costs into HUS and non-HUS categories and into medical

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[2] The estimates for Scotland are in 1994-95£ and were updated to U.S. 1996$ with the product of two multipliers rounded down to 1.6331: (1) 1.578, provided by Riggs Bank, Washington, DC in March 1998, to convert the 1994-95£ to U.S. 1995$ and (2) 228.2/220.5 or roughly 1.0349, to update the 1995$ to 1996$ using the change in the 1995 to 1996 consumer price index for general medical care, annual average, provided by the U.S. Bureau of Labor Statistics.

cost and productivity loss categories after removing the costs of managing the Scottish outbreak as well as removing other costs that have no equivalent in both countries.[3] Although Scottish average costs are lower than U.S. average costs for each of these four categories, total average costs for HUS and non-HUS combined are higher because a higher percentage of Scottish cases were in the more severe and costly HUS category.

Table 2 shows that for non-HUS cases, per case medical costs do not vary much between the two countries while per case productivity losses are 2 to 5 times higher in the United States. In general, medical costs and productivity losses were much higher for HUS patients than for non-HUS patients.

For HUS patients, the relative ranking of the per case productivity losses (*i.e.*, U.S. under human capital approach, Scotland, U.S. under the labor market approach) reflects the relative ranking of the valuation of premature deaths in the United States where the U.S. valuation for premature death ($1,533,000 - $5 million) brackets the Scottish estimate (£2.3 million/$3.76 million). Although most patients do not die prematurely from this illness, the difference in valuation of a premature death in the two countries contributed to the differences in costs.

U.S. Medical Costs Per Case for HUS Double Scottish Costs

The average medical cost per HUS case in the United States ($59,000) is double that in Scotland ($29,793). There are several possible explanations why the HUS medical costs per case differ. First, one of the 11 Scottish HUS cases died after only incurring £16 in medical

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[3] The estimated total cost of the Scottish outbreak projected over 30 years was £11,930,347 (Roberts and Upton, 1997, p . 7) and includes a wide range of costs not included in the U.S. study such as the costs of managing the outbreak (*e.g.*, laboratory, public health, veterinary, and environmental services). Therefore, the items that could not be compared were removed for the current analysis.

costs for one doctor visit. Had she not died so quickly and had she been admitted to a hospital, her medical costs would have raised the average medical cost per HUS case. In contrast, in the U.S. analysis, it was assumed that all people who died first incurred hospitalization costs (U.S. cost estimates for medical treatment are based on Martin *et al.*). Second, medical costs may be higher in the United States than in Scotland (*e.g.*, cost of a kidney transplant). Third, the Scottish outbreak occurred in two towns near Edinburgh and where feasible, health officials treated cases at home instead of in a hospital to preserve hospital capacity. In the Scottish outbreak, a higher proportion of seriously ill people were treated at home thus medical costs were lower. Home care included daily visits from medical personnel and daily blood sample analysis.

HUS Cases and Productivity Losses for Premature Deaths Dominate Cost Estimates

Table 3 shows that HUS accounts for the vast majority of the estimated costs in both countries. In the United States and using the $5 million value of a premature death, HUS accounts for 82.8% of total costs, while the milder, non-HUS cases account for 17.2% of estimated costs (80.2% and 19.8% respectively using the $1,533,000 value). In the Scottish outbreak, HUS cases accounted for almost all of the total estimated costs.

When compared to medical costs, productivity losses for the acute and chronic illnesses dominate the cost estimates: 78.6% of U.S. costs using the $5 million value of a premature death, 62.4% of U.S. costs using the $1,533,000 value of a premature death, and 86% of the estimate for the outbreak in Scotland. The productivity costs dominated the total costs because *E. coli* O157:H7 disease can lead to severe outcomes: chronic kidney failure and death.

CONCLUSIONS

The U.S. and Scottish estimates are similar in that the overwhelming share of *E. coli* O157:H7 disease costs are allocated to HUS and in that productivity costs outweigh medical costs. However, the severity distribution differed because the U.S. estimates were based on national estimates of incidence and assumed half of the cases were mild with no medical care, while the outbreak-based Scottish estimates only captured those who were identified as part of the investigation and who tested positive for *E. coli* O157:H7. As with other outbreaks, the outbreak in Scotland had a higher percentage of more severe cases than found in incidence estimates because the more frequent and milder, sporadic cases are less likely to be reported. It is likely that there were mild cases that were not identified as part of the outbreak and if these cases had been included, both the percent attributed to HUS cases and the total average cost would have decreased.

What is important is that in both countries, *E. coli* O157:H7 disease poses a huge economic burden to society and that children are those most likely to become ill with serious complications such as HUS. Despite high costs, both sets of estimates undervalue true societal costs because many cost components are omitted, such as the valuation of lost leisure time and of pain and suffering. Additionally, there is concern that if another outbreak of the same magnitude or larger occurred in Scotland, there may be insufficient hospital capacity to accommodate all that are ill.

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Table 1.
Differences in Cost of Illness Methods: United States and Scotland

Method	United States	Scotland
Foodborne *E. coli* O157:H7 patients	✦ Estimated annual: 16,000-32,000 patients, 63-126 deaths	✦ 1994 milkborne outbreak, west of Edinburgh: 71 patients, 1 death
Illness severity	✦ 800-1,600 patients have Hemolytic Uremic Syndrome (HUS) (5% of patients); 40-80 of these patients develop sequelae (lifelong kidney failure) ✦ 800-1,600 patients hospitalized with hemorrhagic colitis or bloody diarrhea (5% of patients) ✦ Patients who only visited a doctor: 6,000-12,000 patients (40% of patients) ✦ Patients who did not seek medical care: 8,000-16,000 patients (assumed to be 50% of patients)	✦ 10 HUS cases (14% of patients) 4-6 of these patients develop sequelae ✦ 1 case Thrombotic Thrombocytopenia Purpura (TTP)(neurological complications) (1.4% of patients)--included in the HUS category for the analysis. ✦ 13 other hospitalized patients (18.3% of patients) ✦ 47 patients only visited doctor in acute phase (66%) ✦ Patients who did not seek medical care: unknown
Approach	✦ Cost estimates in 1996$ ✦ Cost-of-illness based on U.S. data ✦ Present value of annual costs for typical US cases ✦ All patients assumed to be 4-year old children (avg. in Martin *et al.*)	✦ Cost-of-illness based on age distribution and severity for a particular outbreak ✦ Present value of projected costs for 30 years ✦ Half of patients under 5 years old ✦ Age distribution 7 months to 84 years
Valuation of premature death	✦ Low: one's contribution to production (Landefeld & Seskin: $1,533,000) ✦ High: risk of death in labor market (Viscusi: $5 million)	✦ Great Britain Dept. of Transport, value of lives lost in fatal railroad accidents : £2.3 million ($3.76 million)
Dialysis	✦ 47% of HUS required dialysis at a cost of $137/day for average of 12 days	✦ 8 HUS cases on dialysis, average cost per case £24,000/yr (439,195) when patient is on dialysis. Patients go on and off dialysis as needed.
Kidney transplant Daily hospital room rate	$125,600/transplant using HCFA data ✦ Regular room $1,016/day ✦ Intensive care $2,032/day	£16,000/transplant ($26,130) £155-257/day ($253-$420) plus drugs and investigations
Physician fees	<u>Mild cases:</u> $124/visit times 1-2 visits/patient plus $50 for tests <u>Hospitalized cases:</u> double hospital room rate to include doctor visits, drugs, etc	<u>Mild cases:</u> £114/patient ($186)[(£69($113) for consultation plus £37 ($60) for investigation)] <u>Hospitalized cases:</u> £163 ($266) visit with general practitioner
Discount rate used for sequelae	3% over their 77-year lifetime	5% over 30 years following outbreak

Table 2.
Estimated Costs Per Foodborne *E. coli* O157:H7 Illness: United States and Scotland[1]

Type of Estimated Cost	United States, assuming: Human capital approach	Labor market approach	Scotland
Medical	$800 (non-HUS) $59,000 (HUS)	$800 (non-HUS) $59,000 (HUS)	$725 (£444)(non-HUS) $29,793 (£18,243)(HUS)
Lost productivity	$1,247 (non-HUS) $99,703 (HUS)	$3,060 (non-HUS) $294,790 (HUS)	$624 (£382)(non-HUS) $185,945 (£113,860)(HUS)
Total	$10,000	$21,350	$34,564 (£21,164)

[1] Human capital approach uses Landefeld & Seskin updated to 1996$ ($1,533,000) for a premature death. Labor market approach uses Viscusi's $5 million midpoint for a premature death. Scottish estimates use £2.3 million ($3.76 million) which is the estimated value of lives lost in railroad accidents.

Table 3.
Components of Foodborne *E. coli* O157:H7 Illness Cost Estimates:
United States and Scotland[1]

Component	United States, assuming: Human capital approach	Labor market approach	Scotland
HUS productivity losses	50.4%	69%	86%
HUS medical costs	29.8%	13.8%	14%
Non-HUS productivity losses	12.0%	13.6%	<1%
Non-HUS medical costs	7.8%	3.6%	<1%

[1] Human capital approach uses Landefeld & Seskin updated to 1996$ ($1,533,000) for a premature death. Labor market approach uses Viscusi's $5 million midpoint for a premature death. Scottish estimates use £2.3 million ($3.76 million) which is the estimated value of lives lost in railroad accidents.