BENEFIT ANALYSIS OF SELECTED SLAUGHTERHOUSE MEAT INSPECTION PRACTICES

by

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ABSTRACT

This study explores the feasibility of adopting benefit analysis to measure federal meat inspection's contribution in preventing major transmissions of tuberculosis, tapeworms, and septicemia (or related diseases caused by *Escherichia coli*) in the human population. The range of resulting benefit estimates was substantial, and the fragmentary character of the data provided an explanation. More accurate data are required for estimating how much human disease would be caused if diseased cattle/poultry entered the human food chain in the absence of federal inspection. Specifically, we need to pinpoint the respective probabilities that infections spread from animals to humans: through aerosol routes; skin penetrations; cross-contamination of foods and/or consumption.

The results of this study are highly speculative and more research is needed to clarify and quantify the animal/human disease linkage before full cost/benefit analysis can be applied.

KEYWORDS: Federal meat inspection, Federal poultry inspection, benefit estimates, regulation

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Assessments of the performance of the Federal meat inspection system have been conducted since its 1906 inception. Few have attempted to evaluate the benefits flowing from inspection activities in order to compare their value with program maintenance costs. Furthermore, previous evaluation studies have paid scant attention to changes in health risks associated with today's technologically advanced agricultural production and food processing systems.

This research explores the feasibility of adopting benefit analysis to measure federal meat inspection's contribution in preventing animal diseases (of bacterial, viral and parasitic origin) and toxic conditions from being transmitted to humans. As the slaughterhouse inspection of carcasses receives the majority of the meat and poultry inspection budget, this inspection stage is examined. Benefits from other inspection functions, such as processing inspection and labeling of meat and poultry products are not evaluated. Furthermore, included in the estimation procedures are only three of those conditions for which carcasses are inspected: tuberculosis, tapeworms, and septicemia. Other health protection benefits are not included because of the difficulty of determining the incidence of human illness that would occur in the absence of such inspections. The omission of these other areas of benefit will thus cause the figures to underestimate the total benefits of the inspection program.

SECTION I. THE ECONOMICS OF MEAT AND POULTRY INSPECTION

Why is the government involved in health protection programs such as meat inspection? Compare the purchase of a pound of hamburger to the purchase of a chair. Not only can one visually determine the chair's sturdiness, one also can sit on it before purchase. If the chair should break at home and cause harm, you have a clear causal link and clear evidence (i.e. the pieces of chair) to show the retailer, and if necessary, the courts. In contrast, a visual examination of the pound of hamburger in the supermarket only reveals discoloration and gross spoilage--both of which might be disguised by the addition of food coloring and deodorizers. Contamination by microorganisms, chemicals, antibiotics and/or hormones potentially harmful to humans cannot be seen with the naked eye. Furthermore, the causal link of consumption of or contact with the meat to human disease cannot be established most of the time--you have eaten the evidence. There may be a long time lag before the disease symptoms occur, and the meat connection does not occur to you. Many diseases are transmitted by a variety of sources, and the same symptoms may indicate several possible conditions (for example, brucellosis causes fatigue which could be attributed to many causes). "By the time one has been diagnosed as tubercular, it will be impossible to know from what source the disease was contracted, much less to be able to present evidence in a law court. The evidence is destroyed with the eating, and only rarely can it be used to point to the source of infection" [169, p. 112] 1/, and consumers cannot buy information on the healthfulness of products--the cost is prohibitively expensive. The laboratory tests for just 20 toxic chemicals that could contaminate a pound of hamburger would cost $625. [133, p. 209]. Thus, perishable foods present a chronic and potential danger to human health, amplified by the magnitude of consumption. For example, meat and poultry products are consumed at a rate of over 220 pounds retail weight per person annually.

Human illnesses from contaminated foods involve both medical costs and income losses. More doctors, nurses, medical technicians, treatment facilities, and equipment need to be added to existing stocks to handle large outbreaks of disease. The value of the output of goods and services that would have been produced by the afflicted persons for the duration of their illnesses must be included in the economic cost. Consequently, the size of the economic loss depends both on the incidence and the extent of the affliction caused by the unsafe meat or poultry product.

Both medical costs and wages lost are direct costs (imposed on the person consuming the meat or poultry) that can be monetized; however, three other categories of costs are not included in this analysis (figure 1): (1) direct costs that cannot

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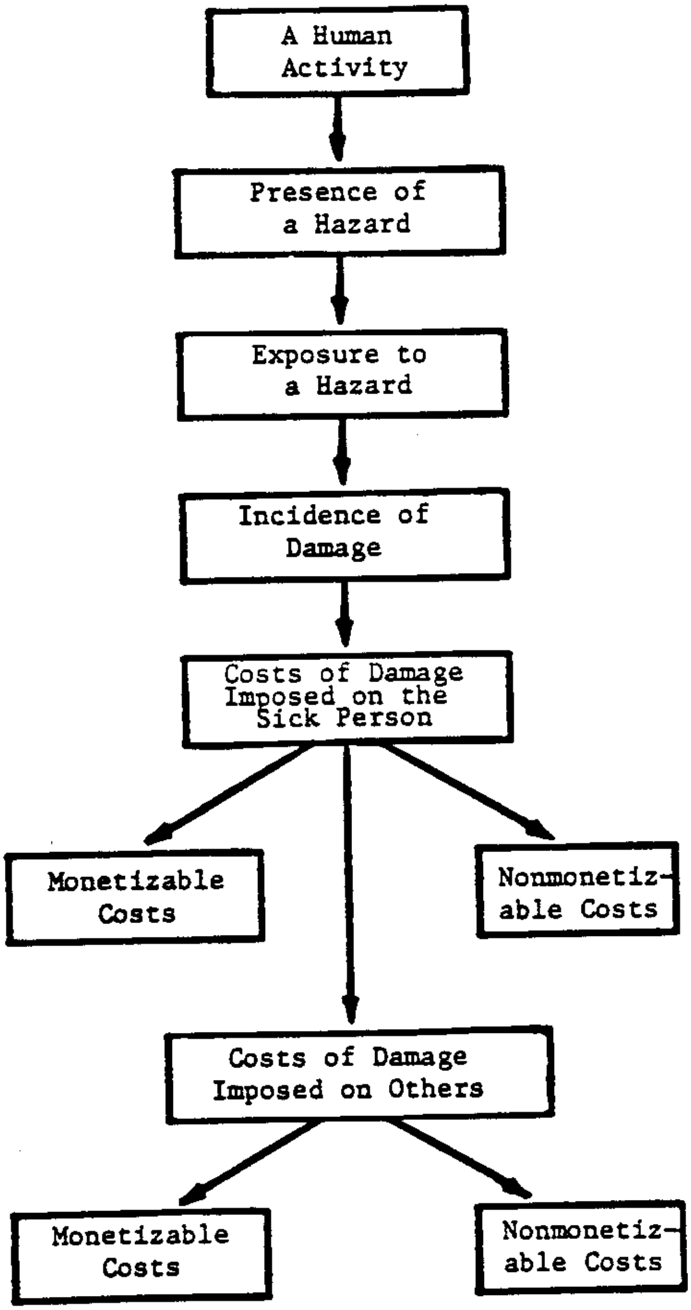
1/ Numbers in brackets refer to sources listed in the references.

FIGURE 1: COSTS FROM HUMAN ACTIVITIES INTRODUCING HAZARDS INTO HUMAN AND NATURAL ENVIRONMENTS



Source: [138]

be monetized, such as the pain and suffering of the sick person; (2) indirect costs (imposed on others) that can be monetized, such as replacement of homemaker and child care services previously provided by the person who is hospitalized or dead; (3) indirect costs that cannot be monetized, such as the pain and anguish of the sick person's family.

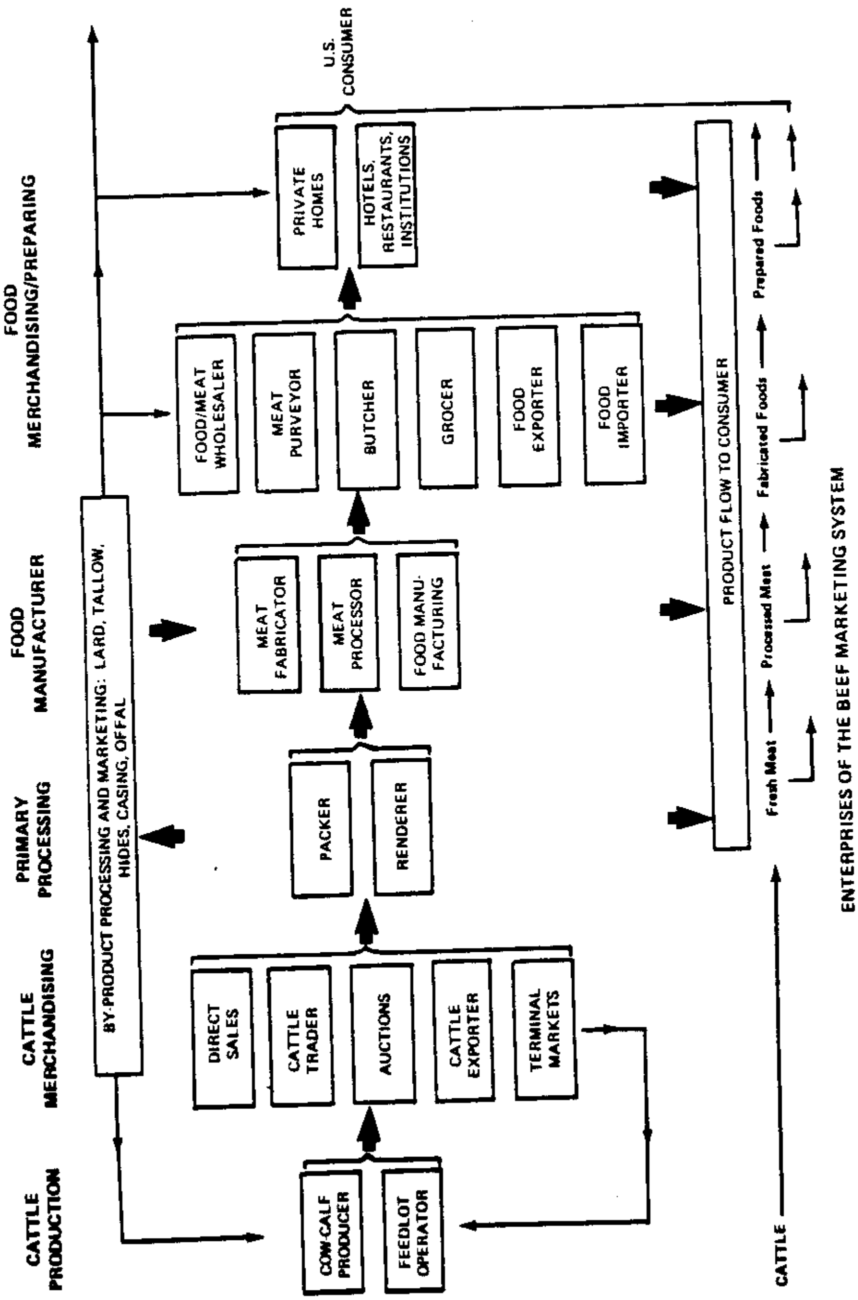
Because the healthfulness or contamination of meat and poultry products cannot be readily determined, there is an incentive to compromise product quality to cut costs. Adding consumer protection features to a product (for example, visual and/or laboratory examination for disease, better refrigeration, or disposal of slightly spoiled products) adds to the cost of production. Firms under perfect competition have no little or no incentive to add such features, particularly since many animals lack identifying marks; the meat is frequently rehandled (see figure 2) and is sold under a generic name as it moves through the marketing system. Such loss of identity, which impedes tracing a product back to the origin of a hazard, can protect an offending firm from detection and involvement in civil suits and payment of claims. Furthermore, consumers cannot readily determine the healthfulness of the product at a point of purchase, but only after great analytical expense. This creates a demand for product safety information to be supplied inexpensively by some reputable organization such as the government.

Figure 3 illustrates the relationship between the total cost function for more intensive inspection of a given quantity of meat or poultry products and the total benefit function to society from the resulting reduction in health hazards. Minimal inspection might consist of nothing more than observation of the product for changes in color or smell indicating decomposition. But procedures for detecting more difficult-to-find hazards, such as chemical residues or microscopic evidence of disease, would add considerably to costs. As the inspection program attempts to find and remove more health risks, the cost function would increase astronomically.

Total benefits increase with the level of inspection because human disease contracted from meat and poultry declines. But if the most important health risks are detected and removed first, then the benefit function will have a diminishing slope. This indicates that the incremental benefits are declining as the inspection effort increases.

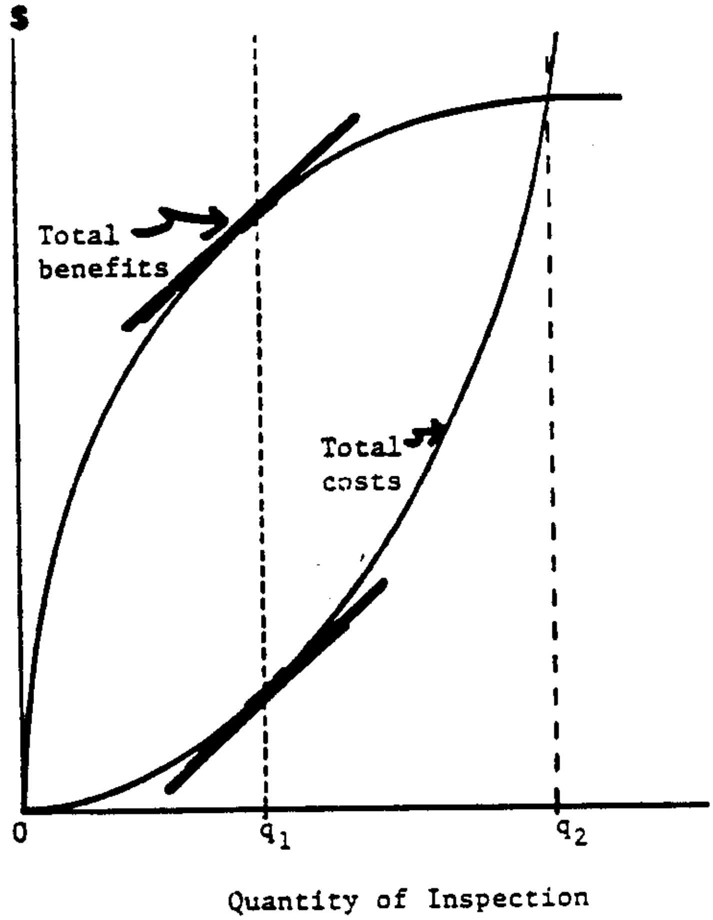
Although figure 3 indicates that total benefits and costs are equal at the q_2 level of inspection service provided, this is not the optimum level of use for inspection resources. The optimum vel q_1 is where the incremental gain in benefit equals the incremental increase in cost. (The equality between incremental benefits and incremental costs is shown by the slopes of the two curves; note that at q_1 the slopes are equal (tangents to the curves are parallel; the slopes, $\frac{dB}{dI}$ and $\frac{dC}{dI}$, are equal). The use of resources greater than q_1

Figure 2: Example of the Complex Beef Marketing System



Source: General Accounting Office: CED-78-153

FIGURE 3: TOTAL BENEFIT AND TOTAL COST FUNCTIONS, BY LEVEL OF INSPECTION INTENSITY AND THE RESULTING HAZARD TO HUMAN HEALTH



would increase costs more than benefits. A reduction in inspection service below q_1 would reduce benefits more than costs. Consequently, the optimal use of inspection resources does not eliminate all risks from consumption of this quantity of meat products.

Our purpose is to determine whether total benefits of some inspection are likely to be greater than total costs (shown as the possible points between 0 to q_2 in figure 3) or less than total costs (the area beyond q_2). Further research could attempt to define where q_1, the social optimum, is for the meat and poultry inspection program as a whole and for its program components.

Inspection does not have to be a Federal Government function. Inspection could be carried out by the producing groups (private industry), religious groups, or even cooperatives, that own and control all the processes from the farm to the retail level. However, there are at least two advantages to a Federal effort. First, Government has the police powers required to enforce minimum standards. Under rigorous enforcement, no single firm has the incentive to lower standards and save costs by selling less safe meat and poultry products. Second, a Government-sponsored system may instill more confidence that the public interest is being protected than would a privately-controlled one. Consequently, the demand for meat will be greater than without Federal inspection. (Consider a baseball league where the umpire is paid by the team and not by the league.)

However, a Government-operated system does present problems. No yardstick exists for measuring performance in terms of efficiency, equity, enforcement and progressiveness, over time. This problem of evaluating performance also occurs with private inspection, but survival of the firm does indicate it is doing something right.

The number of meat and poultry plants currently inspected is eight times the number in 1910, while the inspection workforce is only four times the 1910 size (table 1). In constant dollars, the inspection budget is 12 times the 1910 budget. From 1974 to 1979, plants inspected increased by 14 percent; pounds of meat and poultry inspected at slaughter increased 4 percent, while inspection at the processing level increased 33 percent (figure 3). Yet the 41-percent budget increase was not enough to cover inflation, and the budget measured in constant dollars fell by 5 percent. Given the increasing tasks to be performed, the pressure to increase the budget likely will continue. But, the cost effectiveness of the inspection system is important to a public concerned about the size of government expenditures and inflation.

SECTION II. THE CONTEXT OF THE U.S. MEAT AND POULTRY INSPECTION PROGRAM

Close to the beginning of this century, a Federal regulatory agency was established to set minimum standards of safety and wholesomeness for meat animals, processing methods, and products and to require all firms engaging in interstate commerce to adhere to the Federal standards. State and local officials also enforce similar rules during their inspections. Violations can result in condemnation of the product, or closure of operations. Federal inspection costs are almost exclusively paid from general tax revenues.

Location of Inspection Point

In establishing an inspection program, the government had a choice of locations between the farm and final point of sale (figure 2). The point of final consumption, as discussed, is a very expensive place to inspect. The beginning of the process, the farm, is also difficult because there are hundreds of thousands of farms. Also, many animal diseases are not evident to the naked eye in a live animal and only become obvious when the animal is butchered. (Although new and inexpensive diagnostic tests being developed could change the relative costs and make it possible to test live animals.) Inspectors stationed at the slaughterhouses have the advantage of being able to observe the live animal as well as the intact carcass with lymph nodes and internal organs attached which are often more likely to show signs of infectious disease than the meat itself.

Accurately estimating the impact of federal inspection on a specific human disease was more difficult and tenuous than I imagined. The complexity of the cattle production, merchandising, processing and retailing system permits numerous contact points between humans and live animals and humans and the animal carcass (figure 4). The potential for human illness can occur at any of these points and not just at the point of final consumption.

There are six major ways human illness can come from cattle (table 2). Each of these six pathways is diverse and the examples are not exhaustive:

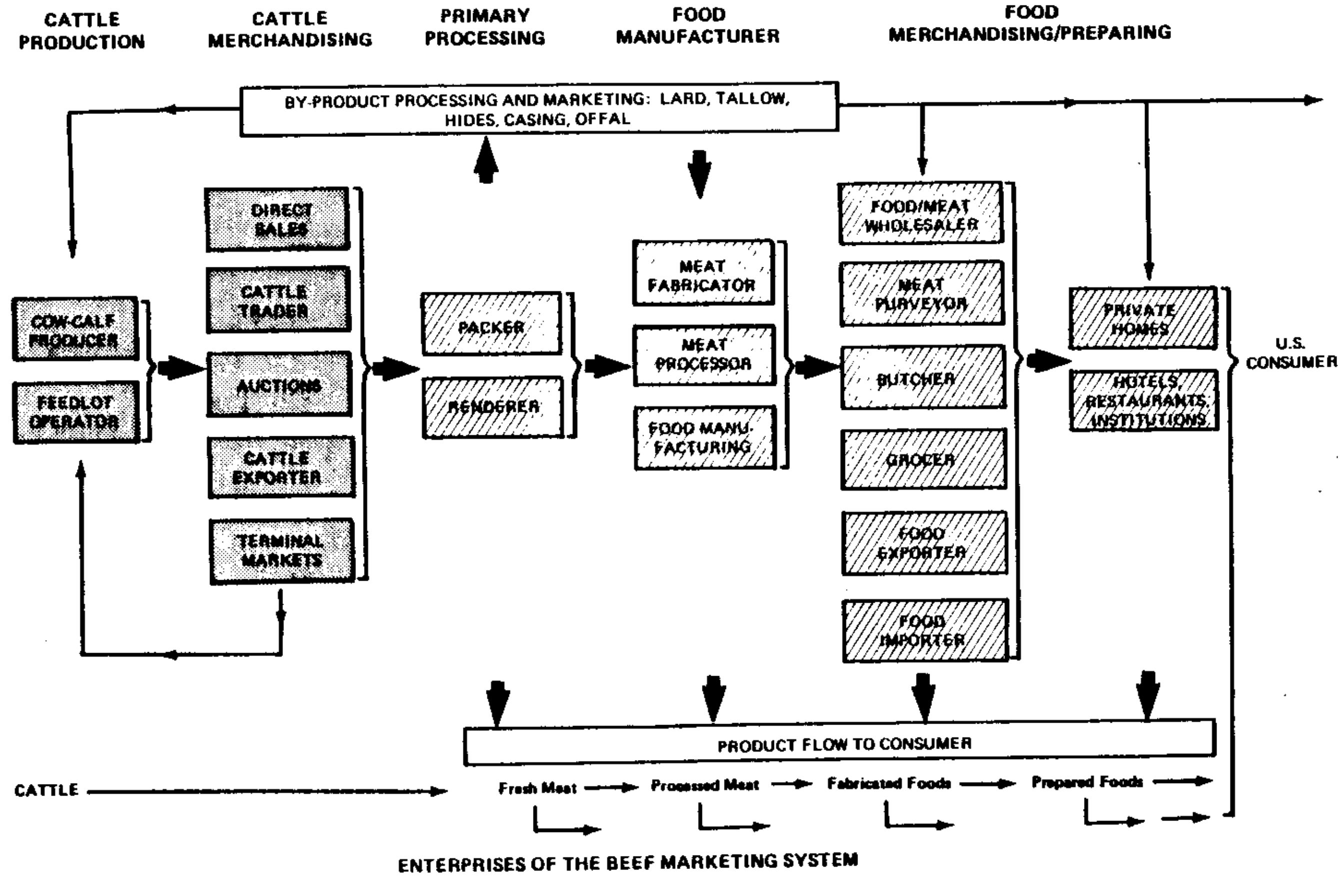
1. Direct contact with the live animal such as a bite or touching a part of the animal.

2. Indirect contact with the live animal. One of the most important is aerosol contamination through breathing or skin contact with organisms floating in the air. Then there is contamination of the animal's general environment--barn, pasture, gates, etc.

3. Direct contamination by the carcass such as penetration of the slaughterhouse workers' skin by pathogens or entry through cuts and knicks in the skin.

4. Indirect contamination by the carcass such as aerosol contamination while the carcass is cut up thereby releasing pathogens into the air or contact with knives.

Figure 4: Potential Health Hazards From Contact With the Live Animal, its Carcass or Consumption of Meat



- Contamination through contact with the live animal either directly or indirectly (e.g. aerosol contamination of an air system as with legionnaire's disease or contact with manure or contaminated barn walls)
- Contamination through contact with the carcass or products thereof (also included are cross-contamination of other carcasses in the slaughterhouse, other meat products in processing or other foods prepared in the same kitchen
- Contamination through eating meat or cross-contaminated products

TABLE 2: PATHWAYS OF HUMAN EXPOSURE TO ANIMAL DISEASES

I. Direct contact with live animal

- Animal bite
- Contact with the skin, fur, tail, etc. and micro-organisms found there

II. Indirect contact with the live animal

- Aerosol contamination of the barn and air system (e.g. legionnaire's disease)
- Contamination of the walls, floor, gates, etc.
- Animal refuse (manure)
- Flies or fleas biting the infected animal and then biting humans and transmitting disease (malaria, bubonic plague)

III. Direct contamination by the carcass

- Some organisms penetrate the skin of personnel handling meat (Bovine Leukemia Virus, Toxoplasmosis)
- Entry of organisms through cuts and knicks on the hand of slaughterhouse or processing plant workers

IV. Indirect contamination by the carcass

- Aerosol contamination when the carcass is cut up and/or slapped on the counter, thereby releasing pathogens
- Contact with knives, wiping cloths, sinks, etc. where pathogens have been deposited

V. Cross contamination of other edible products

- Carcass contaminating other carcasses in the slaughterhouse
- Meat products in the processing plant
- Other raw or cooked foods in the kitchen or a private home or commercial feeding establishment

VI. Consumption of meat and meat products

5. Cross-contamination of other edible products in the slaughterhouse, processing plant, retail stores, or kitchens in eating establishments and homes which then causes human illness when eaten.

6. Consumption of the original diseased meat.

Many federal meat inspection requirements are aimed at minimizing these types of contamination at least for points 3, 4 and 6, and somewhat for point 5. To the extent the condemnations of diseased animals and removal from the human food chain provides an economic incentive to exert better control on the farm, the number of diseased live animals would be reduced thereby reducing human illness contracted from live animals. However, there are other control mechanisms at work too, such as state sanitation inspection of grocery stores and butcheries, firm's quality control programs, and on-farm inspection by USDA-APHIS (Animal and Plant Health Inspection Program).

To determine actual program benefits we must examine the major components of the meat and poultry inspection program, the data available about the program, its statutory and administrative history, the scientific literature on the types of human health hazards that might occur in meat and poultry products, and the context of today's meat and poultry production and marketing system. The legislative history consistently reveals that human health protection, or at a minimum maintaining public confidence in the healthfulness of meat, was the purpose of the program.

Historical Background

During the late nineteenth century, meat inspection was conducted by some city health departments. Slaughterhouses, like the Union Stockyards in Chicago, occasionally hired inspectors of their own. However, foreign countries considered these precautions inadequate. In 1879, Italy stopped importing U.S. pork products because of the fear of trichinosis, a parasite transmitted by eating or handling raw or rare pork. Hungary, Spain, Germany, France, Romania, Greece, and Denmark followed, and the value of U.S. meat exports fell by 40 percent annually [142, 1906 issue, p. 69; 135, p. 8884]. The U.S. Congress responded in 1890 and 1891 by providing for official U.S. Government inspection of salted pork and bacon when required by an importing country or whenever any purchaser, seller, or exporter requested inspection. 2/ This inspection occurred primarily in the packing plant.

The demand by packinghouses for inspection services generally exceeded expectations. Consequently, the U.S. Department of Agriculture (USDA) requested that the Congress appropriate enough money to extend inspection to all applicants. Secretary of Agriculture, Jeremiah Rusk, asked for the authority to establish

2/ Act of August 30, 1890 and Act of March 3, 1891.

an inspection system to "cover all animals slaughtered for human food in order to protect American consumers as well" [142, 1906 issue, p. 76].

The Congress acted on this request in 1906, largely because of conditions exposed by Upton Sinclair's book, The Jungle. 3/ Sinclair had portrayed the Chicago stockyards as unsanitary, rodent-infested places where dead cattle were secretly butchered at night and sausages were composed of unsavory and harmful ingredients. In a hasty move to correct this situation, the Congress added a meat inspection amendment to the annual Agricultural Appropriation Bill. The 1906 act required the Federal inspection of all meat crossing State lines; the first inspection was to be conducted in the slaughterhouse, with subsequent inspections any time the meat was further processed or sold to another company.

Federal poultry inspection began as a voluntary program on an ad hoc basis and was formalized under the authority of the 1946 Agricultural Marketing Act. However, the expansion of the poultry industry (from 1 million broilers raised annually in the thirties to over 1 billion in 1957) and new scientific knowledge about the communicability of poultry diseases to workers were the principal factors leading to the 1957 Poultry Products Inspection Act. 4/ This act mandated the Federal inspection of every poultry carcass that crossed State lines.

Motivated by its desire to lower costs, in 1962 the House Appropriations Committee required the Secretary of Agriculture to survey all State inspection programs. It was thought that USDA could simply certify State inspection programs and thereby save Federal inspection dollars. At that time, however, only 26 States required inspection at the slaughterhouse [132]. A patchwork of inconsistent and conflicting State standards and inspection practices, highlighted by the USDA survey, led the Congress to mandate that State inspection efforts be upgraded to match or equal those at the Federal level. Federal funding was made available to pay for half the State inspection costs. States were also given the option of transferring their entire meat and

3/ Sinclair's book was published in February 1906 after being serialized in a socialist magazine, The Appeal to Reason, which supported him during the 7 weeks he spent in Chicago gathering material. The act (Public Law No.382) was passed as a rider to the Agricultural Appropriation Bill (39 Stat. 669) and was signed on June 30, 1906, the day on which the Food and Drug Act (34 Stat. 768) was signed. The meat inspection program was made permanent by the Act of March 4, 1907 (34 Stat. 1260).

4/ Act of August 28, 1957 (70 Stat. 441). Some diseases mentioned during the congressional debate were staphylococcosis, streptococcosis, salmonellosis, psittacosis, Newcastle disease, erysipelas, and skin rashes [140, pp. 125 and 34].

poultry inspection programs over to the Federal Government. This resulted in a saving to the States, but greater expenditures from the Federal budget. The new regulations were enacted in two parts--the 1967 Wholesome Meat Act and the 1968 Wholesome Poultry Products Act. 5/

Thus, current Federal meat and poultry inspection programs grew out of concern by consumers here and abroad about the healthfulness of U.S. meat. The Federal program was expanded whenever inadequacies were uncovered in industry inspection systems or in State inspection programs. Today, exemptions from Federal and/or State inspection are few--small poultry plants, specific custom slaughter operations, and farm-slaughtered animals. Virtually all the Nation's commercial meat and poultry supply is subject to inspection.

Program Costs and Functions

The acts require that all carcasses and all meat products be inspected. 6/ The interpretation, as reflected in the procedures, emphasizes inspection at the slaughterhouse. Such inspection directly accounts for 55 percent of the Federal inspection budget (figure 6). Consequently, I have focused on human disease prevention at the slaughterhouse level.

USDA's Food Safety and Inspection Service (FSIS) conducts labor-intensive examinations of each carcass and its internal organs, paying particular attention to the condition of the lymph nodes--important indicators that an infectious disease may be present. If the lymph nodes are normal and there is no other visual evidence of disease, the animal is considered suitable for human consumption.

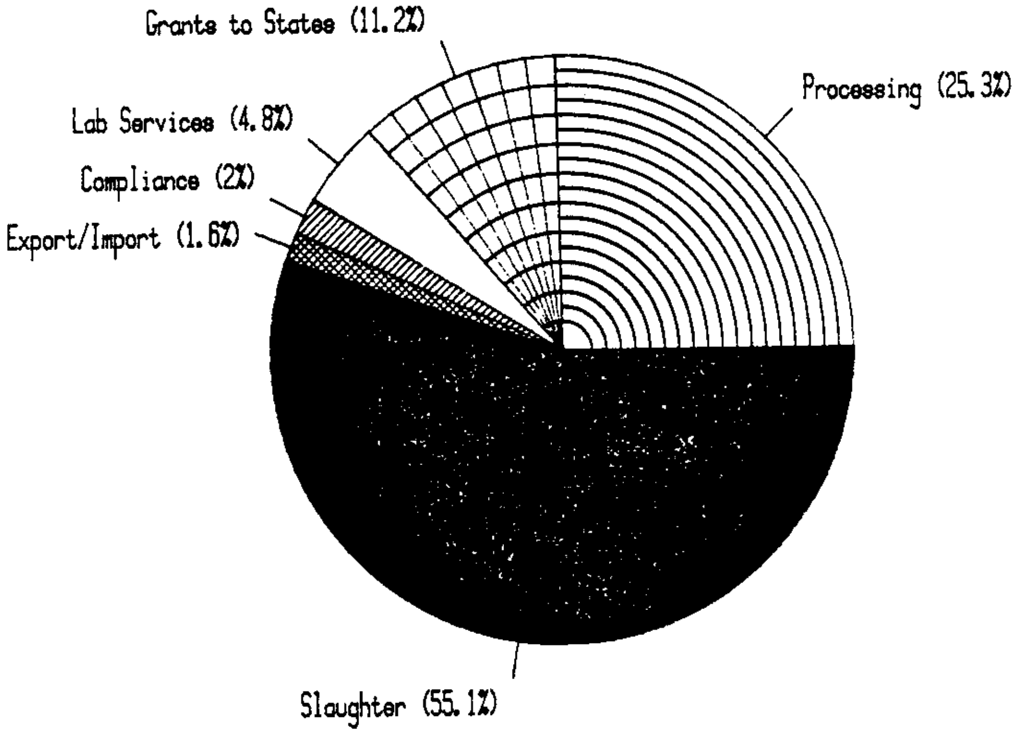
In the early years of meat inspection, 7/ 0.4 percent of all whole carcasses were condemned and an additional 1.7 percent had parts trimmed away. By 1977, the conditions under which animals were raised, slaughtered, and processed had changed substantially. Yet, 0.7 percent of whole carcasses were condemned, and 8.7 percent of the carcasses had parts trimmed away [142, 1908-1911 issues; 148, 1977 issue, pp. 1 and 3).

5/ Act of December 15, 1967 (81 Stat. 584) and Act of August 18, 1968 (82 Stat. 791).

6/ The 1906 Act provided for mandatory inspection of carcasses after slaughter to assure they were "sound, healthful, wholesome and fit for human food." Inspection of meat products was to assure they were "sound, healthful and wholesome and "contain no dyes, chemicals, preservatives, or ingredients which render such meat or meat food products unsound, unhealthful, unwholesome, or unfit for human food."

7/ The years averaged were 1908, 1909, 1910, and 1911.

FIGURE 5: MEAT AND POULTRY INSPECTION BUDGET BY PROGRAM, FY 1979



Source: FSIS FY 1979 Budget

Out of the FSIS budget, 25 percent is spent inspecting processing plants (figure 5). Unlike slaughter inspection, not all processed products are inspected; rather, the emphasis is on monitoring production in the plant. For smaller plants, an inspector is assigned to a circuit of several plants. Larger plants may have one or more full-time inspectors. 8/

During the first 2 years of Federal inspection, almost as much meat was condemned in processing plants as in slaughterhouses. Industry responded quickly by improving sanitation in meat-processing operations. The quantity of meat and meat products condemned at the processing plant dropped by 56 percent, from 43 million pounds in 1908 to 19 million in 1910 [142, 1908 issue, pp. 19-21; 1910 issue, p. 64]. In 1977, with a larger U.S. population and higher per capita consumption, 24 million pounds of meat and meat products were condemned in processing plants each year [152, 1977 issue, p. 6].

Inspectors in processing plants spend approximately 40 percent of their time checking the quality and safety of meat (Is the refrigerator running properly? Is the proper temperature being reached during cooking? Are carcasses being received in wholesome condition?) 9/ Of this time, 30 percent is spent overseeing plant sanitation during processing and cleanup. In the remaining time, FSIS inspectors may check the use of labels, product net weight, and the ingredients actually used in making processed meat and poultry products.

8/ This daily inspection of processing plants is much more intensive than Food and Drug Administration (FDA) inspection of other types of food processing. An FDA inspector visits the plant twice a year at most, and visits may be as infrequent as once every 5 years (depending on the risk category of the plant and type of food processed) [12, vol. II, p. 25].

9/ This breakdown of time spent by function was computed from FSIS's work measurement study, made available by Ken Duff [33]. To derive the three category estimates, we made the following aggregations:

1. Quality and Safety Inspection: (incoming red meat carcasses, incoming product other than meat carcasses wholesomeness and identity of outgoing product, condemned and inedible material, pickle formulation, time and/or temperature process controls, product storage, finished product storage--unrefrigerated, finished product storage--refrigerated, returned goods);
2. Plant sanitation (pre-operative sanitation, in-process sanitation); and
3. Labeling and economic adulteration (new and temporary labels, wholesomeness and formulation of product with two or more ingredients, control of non-meat/poultry ingredients, lot net weight control, Statistical Quality Control (SQC) net weight control).

Laboratory services have been emphasized more in recent years; in FY 1979 they accounted for 4.8 percent of the budget (fig. 4). Most tests now conducted aid inspectors at the processing level; over 80 percent are checks for adulteration and mislabeling. The remaining 20 percent are tissue samples taken from carcasses. Of these, approximately half are to confirm veterinary diagnoses of the carcass' condition and its eventual disposition. The remainder are for tissue samples randomly collected under the National Residue Monitoring Program to determine which chemical residues are occurring at violative levels in the meat supply. Tests are currently being conducted on 52 of the 143 drugs and pesticides likely to leave residues in raw meat and poultry [164, pp. 66-70; 139].

FSIS Data Base

Since the majority of inspection funds are spent at the slaughterhouse, next we examine the data base. FSIS publishes an annual summary of the numbers and reasons for the removal of meat from the human food chain (table 3). FSIS's annual "Statistical Summary" lists 36 causes of carcass condemnations ranging from emaciation to peritonitis to epithelioma (table 3). The general nature of the categories makes it difficult to draw many comparisons to human health consequences. If a random sample of the condemned carcasses were subjected to laboratory analysis, then the causative organisms could be identified and human health linkages more closely predicted. For example, pneumonia in cattle may be caused by around 200 organisms, with very differing implications for humans coming in contact with the live animal before slaughter, the meat during slaughter and processing, and/or consuming the meat.

Continuing down the list, "epithelioma" and "lymphoma" (types of tumors) are other major causes of cattle condemnations, but the causes of cancer and the likelihood of transmission to humans are not well understood.

"Septic conditions" are another major cause of carcass condemnations and one that we did examine in detail as will be discussed. "Deads" are animals which do not rise to their feet when the inspector checks the pens on antemortem inspection and the causes of severe illness or death are numerous. Notice that "residue", such as antibiotics or pesticides, are a minor cause of condemnations and removals for residues has never been large.

Historically, some disease conditions were a large cause of condemnations but are no longer the case today, largely or partly because meat inspection provided the economic incentive to bring the disease under control (table 4). Bovine tuberculosis and cysticercosis (tapeworm) were two such diseases.

TABLE 3: DOMESTIC ANIMAL CARCASSES CONDEMNED, FOR FISCAL YEAR 1981 1/

CAUSE OF CONDEMNATION	NUMBER OF CARCASSES CONDEMNED					
	CATTLE	CALVES	SHEEP AND LAMBS	GOATS	SWINE	EQUINE
DEGENERATIVE AND DROPSICAL CONDITIONS:						
EMACIATION...........................	3,005	1,490	3,304	85	888	101
MISCELLANEOUS........................	2,923	115	29	1	598	16
INFECTIOUS DISEASES:						
ACTINOMYCOSIS, ACTINOBACILLOSIS.....	1,040	1	—	—	9	—
CASEOUS LYMPHADENITIS................	—	—	5,528	172	—	—
COCCIDIOCAL GRANULOMA................	5	—	—	—	11	—
SWINE ERYSIPELAS.....................	—	—	—	—	4,661	—
TUBERCULOSIS NONREACTOR..............	—	—	—	—	4,025	—
TUBERCULOSIS REACTOR.................	26	—	—	—	—	—
TETANUS..............................	13	2	—	—	10	—
MISCELLANEOUS........................	88	3	1	—	83	1
INFLAMMATORY DISEASES:						
EOSINOPHILIC MYOSITIS................	4,962	12	33	1	19	—
MASTITIS.............................	694	—	3	—	36	1
METRITIS.............................	1,356	—	42	—	724	4
NEPHRITIS, PYELITIS..................	3,363	149	534	2	2,855	61
PERICARDITIS.........................	4,251	88	113	2	1,709	3
PERITONITIS..........................	3,707	1,062	207	4	12,239	41
PNEUMONIA............................	9,504	4,041	3,930	44	18,367	152
UREMIA...............................	853	37	1,194	—	1,191	10
MISCELLAENOUS........................	1,551	434	27	3	1,403	9
NEOPLASMS:						
CARCINOMA............................	3,847	27	33	1	1,108	162
EPITHELIOMA..........................	16,451	6	11	3	—	9
MALIGNANT LYMPHOMA...................	9,039	66	10	2	1,307	27
SARCOMA..............................	258	1	9	—	612	18
MISCELLANEOUS........................	632	13	14	—	1,244	50
PARASITIC CONDITIONS:						
CYSTICERCOSIS........................	52	—	314	—	2	—
MYIASIS..............................	2	—	1	—	1	—
MISCELLANEOUS........................	193	—	2,630	1	717	6
SEPTIC CONDITIONS:						
ABSCESS, PYEMIA......................	9,705	447	1,231	8	34,930	39
SEPTICEMIA...........................	7,059	2,799	504	24	8,685	90
TOXEMIA..............................	3,200	374	323	3	3,935	23
OTHER:						
ARTHRITIS............................	1,092	1,516	826	1	20,638	5
CENTRAL NERVOUS SYSTEM DISORDERS....	103	17	7	—	115	2
CONTAMINATION........................	—	—	—	—	9,146	—
DEADS................................	8,735	13,698	4,852	83	82,799	264
ICTERUS..............................	505	2,588	1,059	3	12,917	10
INJURIES.............................	2,825	533	265	9	4,199	43
MORIBUND.............................	1,882	1,165	484	1	1,144	11
PIGMENTARY CONDITIONS................	138	18	14	1	637	99
PYREXIA..............................	146	29	4	7	125	1
RESIDUE..............................	154	278	—	—	61	—
SEXUAL ODOR..........................	—	—	—	—	187	—
MISCELLANEOUS GENERAL................	221	196	40	5	4,830	6
OTHER REPORTABLE DISEASES............	64	12	1	—	47	3
TOTAL................................	103,644	31,217	27,577	466	238,214	1,267

1/ Data used in this report are for domestic animals only. The rates of condemnation would pertain to animals slaughtered abroad only by chance [152].

TABLE 4: COMPARISON OF LEADING CAUSES OF CONDEMNATION ON POSTMORTEM INSPECTION 1917, (percentage of total condemnation)

CATTLE BY CAUSE

Tuberculosis	- 46%
Actinomycosis	- 36%
Cysticercosis	- 7%
Tumors & Abscesses	- 2%
Emaciation	- 1%
(All Other)	- 7%

SHEEP BY CAUSE

Caseous Lymphadenitis	- 44%
Cysticercosis	- 21%
Abhesions	- 14%
Tumors & Abscesses	- 5%
Pneumonia, Etc.	- 4%
(All Other)	- 12%

SWINE BY CAUSE

Tuberculosis	- 83%
Adhesions	- 1%
Tumors, Abscesses	- 1%
Injury	- 0.5%
Hog Cholera	- 0.5%
(All Other)	- 14%

TOTAL DISPOSITIONS

Dispositions	% of Total
Passed without Restriction	= 91.8%
Carcasses-Condemnation	= 0.4%
Retained-Trimmed	= 6.6%
Retained-Parts Condemnation	= 1.2%
Total	100.0%

SOURCE: [12]

SECTION III: BENEFIT EVALUATION

The purpose of the inspection program is to provide at least two types of benefits: (1) the protection of U.S. citizens from a variety of diseases that could be contracted from unsafe meat and poultry products and (2) the opportunity to sell in international markets which increases the income of U.S. agriculture.

It is impossible to measure all the human health protection benefits, as the incidence rate of diseases without inspection is unknown. However, two of the diseases studied--tuberculosis and E. coli septicemia may be among the most important regarding their human health consequences. All three animal/human diseases studied (including beef tapeworms) do not typically cause noticeable changes in the animal. Without Government intervention, farmers and processors buying these animals have little economic incentive to initiate programs to remove these hazards.

Federal inspection of products for export is a source of health protection benefits for foreign consumers. It is unlikely that domestic animal producers and processors could produce for the overseas market without a reputable independent inspection system to assure product safety.

Domestic Human Health Protection Benefits

The methodology adopted to estimate the benefits of meat inspection in preventing disease in humans consists of four steps:

1. Estimate the number of animals likely to have the particular disease that would not be condemned or removed from the food supply each year in the absence of the Federal inspection program.

2. Estimate the number of humans who would be afflicted annually by working with these animals and/or handling or eating the raw or rare meat.

3. Estimate the medical costs required to treat the patients.

4. Estimate the earnings and productivity lost because of the illness. The sum of these costs and lost earnings and productivity represents the economic benefit of inspection for the particular disease.

The four step analysis sounds easy, but it is fraught with difficulty. Some of the unanswered questions that make this analysis tenuous are: identifying exactly which organisms cause disease in cattle; predicting whether these organisms will be spread throughout the carcass or confined to specific locations; predicting the continued survival or growth of these organisms through the food storage, preparation and cooking processes; the number of organisms needed to infect a human; and estimation of the human health consequences either of ingesting these organisms or coming in contact with them while butchering carcasses or preparing food in the home or commercial feeding facility.

This partial quantification of benefits does not include the inconvenience, pain, and suffering of the victims (nonmonetized direct costs) and the indirect costs imposed on others (figure 1). Furthermore, it does not include other human diseases avoided (some are listed in appendix A), the benefits derived from a reduction of possible environmental contamination from meat and poultry during processing, the benefits from accurately labeled meat and poultry products, or the benefits of export sales of U.S. produced meat and poultry products which would be jeopardized by abolishing Federal inspection.

Bovine Tuberculosis

One of the most studied animal diseases, bovine tuberculosis, accounts for a large expenditure of funds by the Federal meat inspection program. Each and every bovine animal slaughtered for meat is inspected. Roughly 70 percent of the inspector's time on the beef slaughter line is spent examining lymph nodes for signs of a wide variety of infections or neoplastic processes, one of which is tuberculosis [53]. The inspector slices and inspects the lymph nodes in the head for evidence of calcium deposits indicating tuberculosis and visually examines and feels the lymph nodes in the inner cavities for such calcium deposits. Cattle carcasses are condemned and removed from the human food chain if TB has spread throughout the whole body. The carcass can only be used for pet food and is almost a total economic loss to the owner. It is passed for cooking if the live animal reacted to the tuberculin test or if localized lesions in the lymph nodes are discovered (these are then removed from the animal) [119]. Since the carcass can only be turned into lunch meats for human consumption, the owner's economic loss is around 50%.

During the 75 years of the Federal meat inspection effort there has been a marked decline in number of cattle with bovine tuberculosis. In the early days of inspection, 25,000 head of cattle were condemned annually for TB (0.34% of cattle inspected from 1908-1911) while today less than 100 cattle, on average, are condemned for TB each year although the number of cattle federally inspected is four times greater. How do we evaluate the impact of inspection on the decline in bovine tuberculosis? How do we measure the value of this decline in bovine tuberculosis in terms of the likely health consequences?

Estimating the Decline in Infected Cattle. Starting with the impact of federal meat inspection on the decline of bovine tuberculosis, we have to consider other events during the past 75 years such as the on-farm tuberculin testing program. What are some possible options for dealing with bovine tuberculosis? 10/

Option 1: Do nothing. Let bovine tuberculosis continue to infect more cattle and humans. This option is viable if the costs of control are very high and thus greater than the benefits of preventing human disease.

Option 2: Rely on voluntary control by farmers. Farmers have the greatest economic incentive to control disease when it spreads rapidly among animals and causes a readily apparent illness that results in a sharp decrease in the economic value of the animals infected before the animal has spread the disease to other members of the herd. None of these conditions are met with bovine tuberculosis:

(a) There is no way to predetermine which cattle will get TB since TB hits healthy cattle as readily as unhealthy and all breeds are equally likely to be infected [87, p. 46]. Thus the farmer cannot screen or isolate cattle from the risk of tuberculosis.

(b) Infected and contagious animals may not develop disease for years, even though they are spreading TB to other animals and humans. And the course of the disease is not steady: "In adult cattle as in people, the disease may exhibit periods of remission and exacerbation" [Ibid., p. 167].

(c) Diseased animals do not act acutely ill or give other obvious symptoms of illness. By the time the disease is visible to the human eye, it is very advanced and "nearly always fatal to the animal" [Ibid., p. 40].

10/ Conventional methods of prevention or treatment are not listed as options because they are not effective against TB: there is no effective vaccine against tuberculosis and drug treatment in cattle does not free the body of tubercle bacilli but merely suppresses signs of disease and after drug treatment is stopped, active disease and shedding of infective organisms continues [87, pp. 167, 51-54].

Option 3: Do on-farm tuberculin testing only. Tuberculin testing has problems with false positives and false negatives 11/ as well as being expensive when the numbers of tuberculous animals declines. 12/

Option 4: Do slaughterhouse inspection only. However, slaughterhouse inspection, while more certain, only catches those animals brought to the slaughterhouse and does not detect other animals left on the farm.

Option 5: Do both slaughterhouse inspection for TB and on farm tuberculin testing, i.e. the present system.

Tuberculin testing of cattle on the farm was very important in the early years in discovering unknown pockets of tuberculosis. Today, however almost all cattle infected with tuberculosis are found through inspection in the slaughterhouse. For example, there were 20 herds discovered to be infected with tuberculosis during FY 78, of which 9 herds were traced directly from the inspection at the slaughterhouse to the farm of origin. An additional 10 herds were indirectly traced, bringing the total to 19 out of the 20 discovered through federal meat inspection [68]. A separate research study would be needed to determine conclusively the relative importance of meat inspection versus farm inspection in causing the rate of tuberculosis among cattle to decline. We have arbitrarily assigned them equal importance meaning that 50 percent of the decline in the observed rate of tuberculosis among cattle has been attributed to meat inspection.

11/ "The reaction to tuberculin is due to sensitivity to tuberculoprotein which develops in the tissues of animals a few weeks after the initial invasion of tubercle bacilli" [87, p. 45].

"The reactor rate among tuberculosis free herds was 1.52% and 0.27% were proved to be caused by Mycobacteria tuberculosis or bovis" [Ibid., p. 266]. Thus the false positives were 1.27% which is eighty percent of the cattle reacting to the test. These false positives may be due to other acid-fast organisms or infections with other types of mycobacteria, or perhaps such an early stage of infection that no signs of disease were yet to be found.

False negatives are also a problem. The World Health Program of the UN reported that, "Unfortunately, some animals that do not react are suffering from advanced open tuberculosis" [Ibid., p. 362]. And the test can be tampered with by injecting tuberculin to desensitize cattle temporarily so they will not react when the official test is made [118, p. 13].

12/ Dr. A.F. Ranney, Chief, Tuberculosis Eradication Section of the U.S. Department of Agriculture reported that New York State estimated in 1953 costs of $738.97 to find a tuberculin reactor by routine farm testing, but only $32.25 to find a reactor after reports of tuberculous lesions were submitted by veterinary meat inspectors [87, p. 37]. These cost differences would be even more pronounced today as the number of tuberculous cattle has continued to decline.

The incidence rate of inspected cattle condemned for tuberculosis in 1908 through 1911 was 0.34 percent, 34 out of 10,000. Multiplying this rate by the average number of cattle carcasses inspected annually (in the last five years this was 34,419,680 carcasses) yields 120,125 cattle which would have had TB if its prevalence had remained as high as it was in the early years [152, 1976-80]. The actual number of condemnations for tuberculosis in the last 5 years was only 95 carcasses annually--leaving a net difference of 120,030 carcasses per year representing the decline in cattle intended for the human food supply which were infected with *Mycobacterium bovis*. Assuming that meat inspection was responsible for 50 percent of the decline, the federal program prevented 60,015 diseased cattle carcasses from entering the human food chain.

The Likelihood of Infected Animals Causing Human Illness. The epidemiological data base for linking animal infection to human infection is still somewhat hypothetical. While half of all human infections were of animal origin in 1921, drinking unpasteurized milk was the primary mode of transmission then [87, p. 128]. Inhalation of bacteria is another mode of transmission and the primary method of people infecting other people and of animals infecting other animals [57, p. 306]. Formerly, prolonged exposures were thought necessary. However a fraction of a minute may suffice to pass tubercle bacilli [87, pp. 46 and 165]. Inhalation would be a possible method of infection of farm families and slaughterhouse workers including those in the processing plant, since bacteria can also be spread through the air when slabs of meat are thrown on the counter and the carcass is cut-up. 13/ There are documented cases of wound infections causing tuberculosis in butchers and veterinarians [57, p. 320].

The risk to the public of eating undercooked tuberculous meat has not been clearly established, although the hazards of eating tuberculous meat have been recorded in the Talmud and the laws of Moses [41, p. 83]. "There is little doubt that the meat of cattle with generalized tuberculosis can contain tubercle bacilli. In one study, samples of muscle from such cases were positive in

13/ "Recent critical analysis of data has shown that droplet transmission is much more frequent than previously thought. When human infection with *M. tuberculosis* decreases in the presence of cattle tuberculosis, the majority of human pulmonary tuberculosis can be due to *M. bovis*. It is agreed that man is as susceptible to bovine as to human tubercle bacilli" [57, p. 306].

Slaughterhouse workers are also exposed to the possibilities of cross contamination. Living tubercle bacilli were found on the surfaces and cleavage planes of a high percentage of apparently healthy carcasses by Lillengen in 1945. The likely source was contamination of carcasses at slaughter since he found bacteria on 71% of utensils, 100% of wiping cloths and 68% of floor samples after cold water sluicing [41, p.37].

50-80 percent" [57, p. 320]. Tubercle bacilli "remain viable and virulent for many weeks in dark, cool, and damp places. They tolerate freezing in ice" but do not tolerate much heat 14/ and survive only two to eight hours when exposed to sunlight. The prevalence of human tuberculosis from drinking unpasteurized milk at the turn of the century, indicates that the bacteria can survive the stomach acids. Perhaps the likelihood of human infection centers around the number of bacteria needed to cause disease. But these data are not conclusive. In one experiment, half of the guinea pigs injected with small numbers of bacilli developed tuberculosis [41, p. 37]. 15/ However, rabbits and guinea pigs fed tuberculous meat slaughtered under asceptic conditions did not become ill [96, p. 232]. 16/

How may one combine such fragmentary data to derive the human risk of tuberculosis from aerosol contamination, penetration of the skin through cuts and nicks, and via consumption of meat (table 5)? I asked an expert to synthesize the data; Dr. James Steele, Public Health Veterinarian, at the University of Texas and formerly Assistant Surgeon General for Veterinary Medicine in the U.S. Public Health Service. He estimated that 4 to 10 human infections (primarily among farm families and slaughterhouse workers) would be caused by each 10 infected live cattle or carcass thereof. Of those persons becoming infected, 90 to 95 percent will be able to resist disease and only 5 to 10 percent will actually develop clinical disease symptoms requiring treatment. The human health consequences of 60,015 tuberculous cattle entering the human food chain are 24,000 to 60,015 human infections of which 1,200 to 6,002 will result in human disease and of those diseased 72 to 360 people will die (figure 6).

14/ In milk or other material, a temperature of 186° F maintained for one minute destroys all bacilli. This can be accomplished also by maintaining a temperature of 142-145° for 30 minutes (Pasteurization)" [87, p. 43].

In pot roast or cuts of meat that are cooked for a long period of time, the bacteria would be destroyed. However, it is possible they would survive in other cuts of meat. For example, the internal temperature of a well done roast only reaches 170°, not 186°. And a medium roast reaches 160° while a rare roast reaches 140°.

15/ Injection of guinea pigs with muscle tissue from tuberculous calves caused all ten guinea pigs receiving the larger dose (1 gram of tissue injected) to develop tuberculosis but only five of the ten receiving a smaller dose (0.01 gram of tissue injected) became ill. Francis hypothesized there were 100-200 bacilli per gram of muscle tissue. Injection of blood samples was not as infective; only two guinea pigs receiving the injection developed TB while four did not [41, p. 37].

16/ However, animals fed such meat slaughtered under the primitive conditions used before the turn of the century did develop tuberculosis [96, p. 232]. The difference may have been that internal organs which were sites of lesions were eaten in the latter case and thus greater concentrations of bacteria were ingested.

TABLE 5: PATHWAYS OF HUMAN EXPOSURE TO BOVINE TUBERCULOSIS

I. Direct contact with live animal

- Animal bite
- Contact with the skin, fur, tail, etc. and microorganisms found there

II. Indirect contact with the live animal

- Aerosol contamination of the barn and air system (e.g. legionnaire's disease)
- Contamination of the walls, floor, gates, etc.
- Animal refuse (manure)
- Flies or fleas biting the infected animal and then biting humans and transmitting disease (malaria, bubonic plague)

III. Direct contamination by the carcass

- Some organisms penetrate the skin of personnel handling meat (e.g. toxoplasmosis and bovine leukemia virus)
- Entry of organisms through cuts and knicks on the hand of slaughterhouse or processing plant workers

IV. Indirect contamination by the carcass

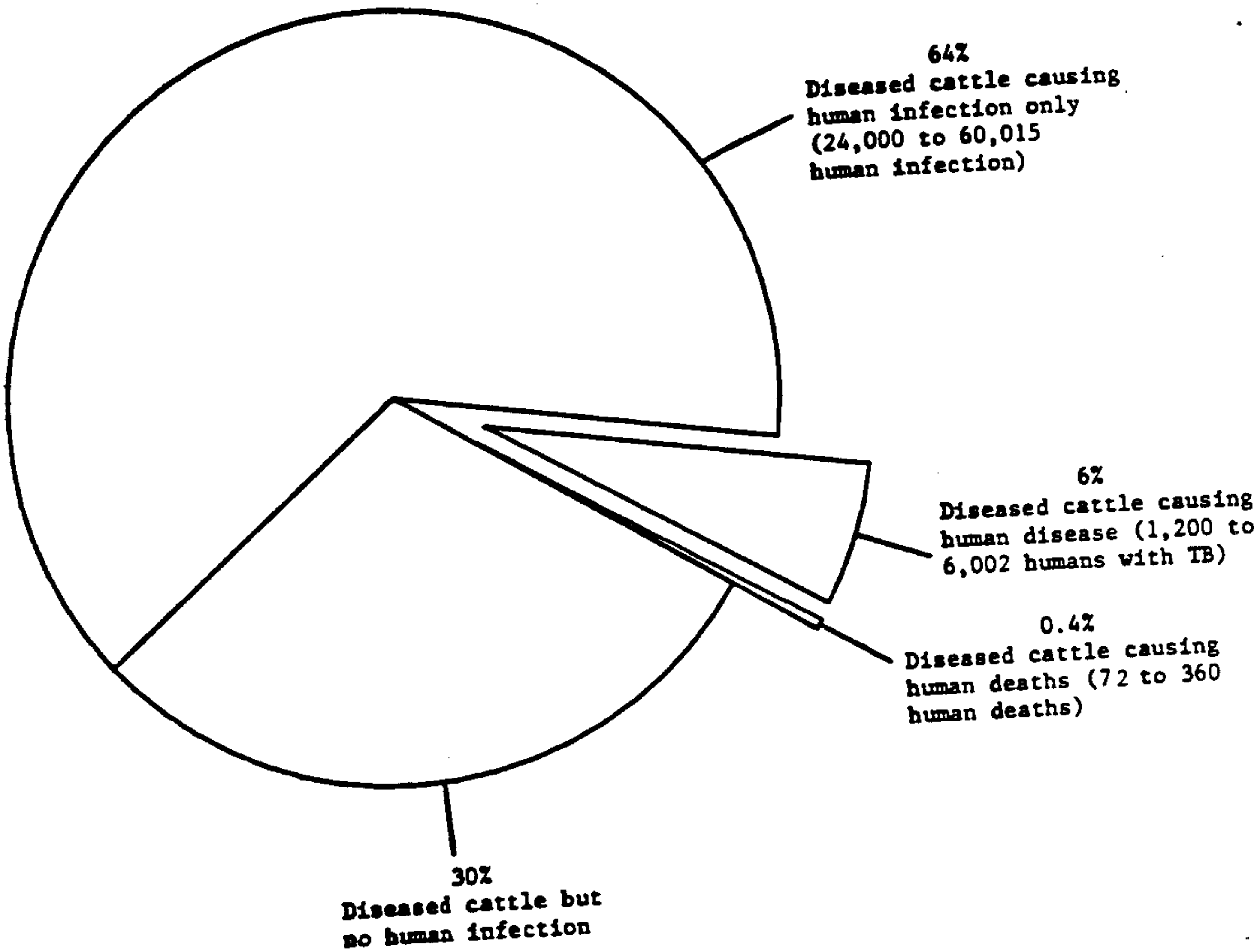
- Aerosol contamination when the carcass is cut up and/or slapped on the counter, thereby releasing pathogens
- Contact with knives, wiping cloths, sinks, etc. where pathogens have been deposited

V. Cross contamination of other edible products

- Carcass contaminating other carcasses in the slaughterhouse
- Meat products in the processing plant
- Other raw or cooked foods in the kitchen or a private home or commercial feeding establishment

VI. Consumption of meat and meat products

FIGURE 6: ESTIMATED HUMAN DISEASE AND DEATH CAUSED BY ASSOCIATION WITH 60,015 TUBERCULOUS CATTLE



Cost of Treatment for Human Tuberculosis. "In 1937, Raw stated that the bovine type of tubercle bacillus may cause practically every kind of lesion that the human type is capable of causing in the tissues of man. Cases of tuberculosis of the lymph nodes, bones, joints, meninges, and other organs, have been proved to be caused by the bovine type of bacillus" [87, p. 62]. Furthermore, "Griffith did not find it possible to distinguish clinically or by x-ray inspection between the human and bovine type of pulmonary lesions in man" [Ibid., p. 63]. Once a tuberculous lesion develops in an organ, the appearance and course of disease is the same whether *M. bovis* or *M. tuberculosis* is isolated, including the character and extent of lesions seen at autopsy [57, p. 306]. Consequently we have used average cost data for all human TB cases.

Some of the nonfatal tuberculous cases can be treated on an out-patient basis (approximately 18 months); however, others require extensive hospitalization. The Centers for Disease Control (CDC) of the United States Public Health Service, Department of Health and Human Services which monitors tuberculosis reports that a fictional "average" case in 1977 would have required 30 days of hospitalization [95]. 17/ Today, half the tuberculosis patients are in general care hospitals and half are in sanitariums [159, p. 17]. The average cost per day multiplied by the average 30 day length of stay yields a cost of $4,500 per case [45] (table 6). An additional $250 is needed for drugs and approximately $1,250 for laboratory tests, chest x-rays, eye tests, nurse and physical visits and tracing of contacts [91]. On average, 2 months are lost from work, adding another $2,275 per case. 18/ Thus the total direct money costs per individual who recovered from tuberculosis would average $8,275 (table 6).

Benefits of Preventing Deaths from Tuberculosis. Although treatment for TB improved dramatically after the discovery of streptomycin in 1944, still around 6% of the patients die. The proper method of evaluating human death has been much debated in the economic literature [38, pp. 184-190]. Dorothy Rice of the National Center for Health Statistics has pioneered in calculations of the present value of human capital which essentially

17/ This average figure includes hospitalization of those who died. The movement away from tuberculosis sanitariums towards out-patient care is reflected in this decline in hospitalized days which was as high as 145 as recently as 1970.

18/ The two months of lost wages or work time are low because they are the average weekly earnings for private sector production and non-supervisory workers on nonagricultural payrolls, reported by the Bureau of Labor Statistics as $261.89/week in December 1981. It is assumed that all persons affected would be workers or that the value of time lost to nonwage earners (perhaps children, homemakers, students, the elderly) would be roughly comparable to the value of wages lost.

TABLE 6: BOVINE TUBERCULOSIS COSTS AVOIDED

Type of Cost	Cost per Case	Total: Low estimate 1,200 cases	Total: High estimate 6,002 cases
	Dollars	Million dollars	
Medical costs, total		7.2	36.0
Hospital	4,500	5.4	27.0
Physician and nurse visits	1,250	1.5	7.5
Drugs	250	0.3	1.5
Lost wages, total		9.2	118.6
Due to illness*	2,275	2.6	12.8
Due to death**	92,000 low 294,000 high	6.6	105.8
Grand total		16.4	154.6

*The lost wages due to illness only are calculated for 1,128 individuals (low estimate) and 5,642 individuals (high estimate).

**The estimated number of deaths are 72 (low estimate) or 360 (high estimate) persons and the low loss of life figure uses the human capital approach (appendix B) while the higher figure is the willingness to pay approach (appendix C).

measures the loss of productive capacity caused by the death of a worker. These numbers have been updated to include inputed values for housekeeping services performed by the individual (appendix B).

Economists have long contended that while the human capital approach captures an important piece of an individual's contribution to society and Gross National Product (GNP), an improved theoretical concept is an individual's "willingness to pay" to reduce the risk of death [84, pp. 159-163, 38, pp. 184-190]. Landefeld and Seskin have just published their "Adjusted Willingness-to-Pay/Human Capital" estimates which are significantly higher than the traditional human capital estimates for three reasons: (1) the non-labor income such as pensions are included since these resources can be used to pay for a reduction in the risk of illness; (2) risk aversion is assumed using data from life insurance purchases which means that a family will pay more than their expected economic loss to buy peace of mind and reduce the risk of income loss due to death of a wage earner; and (3) a lower discount rate is used which reflects the individual's opportunity cost of investing in other risk reducing securities or assets--"such as installing a security system or buying a safer car" [71, p. 562].

This new estimate increases the value of life more than threefold over the previous estimate of $92,000 per life to $294,000 per life for the age distribution of deaths from tuberculosis as reported by the Centers for Disease Control (CDC) and shown in appendices B and C. If these figures more accurately reflected the value of life, then the TB deaths avoided are valued at $21.2 million for the low estimate (72 deaths) to $105.8 million for the high estimate (360 deaths).

Conclusion. The aggregate costs for TB patients who recover plus those who would die are shown in table 6. The medical costs avoided range from $7.2 million for the low estimate to $36.0 million; lost earnings or productivity cost range from $9.2 million to $118.6 million; and these sum up to estimated benefits ranging from a low of $16.4 million to a high of $154.6 million.

It is hard to assess the incidence of meat-related TB and the value of reducing TB. First, the implementation of slaughterhouse inspection began only a decade before the on-farm tuberculin testing for tuberculosis. Thus two control points were used simultaneously. Both methods of detecting tuberculosis continue to be used today, albeit the vast majority of the discoveries of infected herds come either directly or indirectly from the slaughterhouse detection. Furthermore, the decline in human cases of bovine tuberculosis cannot be attributed solely, or even largely, to slaughterhouse inspection since drinking contaminated milk was the more common source of cattle/human transmission and since pasteurization of milk became common around the same time (the temperatures for pasteurization were based on the destruction of tubercle bacilli). Human cases of TB may take ten, or even thirty, years after infection to manifest themselves. Thus there are no good data on which to base a causal linkage between the beginning of inspection and the reduction in human cases of bovine tuberculosis.

Second, bovine tuberculosis in humans is difficult to differentiate from the more usual human TB (caused by *Mycobacterium tuberculosis*) unless serological tests are done or unless the person develops a hunchback.

In addition, there are joint costs involved in the inspection process since the examination of the lymph nodes for signs of TB may uncover other infectious diseases. How does one allocate the costs of inspecting lymph nodes among the various infectious diseases? Which disease is the primary one shouldering the costs? And what are the secondary diseases whose incremental costs might be only one-tenth as much?

From a theoretical perspective, the best vantage point for evaluating the human cases of disease prevented would be to compare the human infections caused today by cattle with what would have been the case in the absence of the program. But the rub here is, what kind of decline in bovine tuberculosis could be expected among cattle with just on-farm tuberculin testing? Would the testing have expanded greatly beyond its actual role, or would the high costs in the absence of leads from the slaughterhouse have curtailed the effort? 19/ Or would there have been some other changes in farm management and animal husbandry practices which would have altered the incidence among cattle?

Looked at from another perspective, since the program has been so successful in reducing TB, we could consider abolishing the inspection for TB today and estimating the human health consequences. Then examining the likely spread of disease among herds would be the basis of the analysis. The Animal and Plant Health Inspection Service (APHIS) in USDA has developed such a model based on the abolition of all Federal efforts against bovine tuberculosis [70]. The spread of disease was based on the probability of purchasing infected cattle from tuberculous herds. In 25 years five percent of the cattle would be infected, the level of infection in 1906 when federal meat inspection was established. The APHIS model stopped at 40 years when 9% of the cattle would be infected and the rate of infection would keep spreading. In 1958, 17-18% of all cattle in England were estimated to be tuberculous and because the disease increases with age, 40% of the cows slaughtered were tuberculous [41, p. 7]. 20/

From yet another perspective, a historical context, a higher benefit estimate is obtained than either methodology just

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19/ See footnote 12 on page 23.

20/ Bovine tuberculosis is a world-wide problem. In the 1940's the incidence of disease in milk cows in Europe was estimated to range from 10 to 70%. In Latin America the incidence ranged from 10 to 30% and higher near metropolitan areas. Australia and New Zealand were thought to have a 7% rate of infection. A survey in China around Peiking estimated 18% were infected [87, p. 189].

discussed because the human health consequences were much more severe then. In 1906, bed rest was the treatment for human TB since the available drugs were not effective. This discovery of streptomycin in 1944 meant TB became treatable with drugs and today the human death rate has fallen to 6 percent of those becoming ill.

Beef Tapeworm

There are a number of worms infecting humans that use meat as a vehicle. Taenia saginata is probably the most common worldwide. Around 45 million people have been estimated to harbor Taenia saginata--11 million in Europe, 15 million in Asia, 18 million in Africa and 1 million in South America [98, p. 79]. North America and Australia are left out of this tally, but also have problems. In 1917, near the beginning of the U.S. Federal inspection effort, T. saginata was the cause of 7 percent of all cattle condemnations, or 0.28 percent of all cattle inspected (table 4). Today the incidence of tapeworm condemnations has fallen to a total of 765 cattle carcasses from 1977-1981, or 153 per year. However, if dead cysts are found in small numbers, then the carcass is passed for freezing to kill any undetected cysts--these averaged over 10,000 carcasses annually from 1977 to 1981 [152].

Eating one live larvae in raw or rare meat and not killed by thorough cooking will cause a tapeworm in human intestines where it will live until the death of the individual unless medical treatment is provided (table 7). Symptoms vary in their intensity and some persons never realize they have a tapeworm. However most people experience symptoms which "...may include nervousness, insomnia, anorexia, loss of weight, abdominal pain, and digestive disturbances" [7, p. 319]. Occasionally the appendix, uterus or biliary tract are invaded and serious disorders can occur [57, p. 679].

Humans are the definitive hosts of tapeworm. A mature tapeworm will shed 8 or 9 egg cases daily totaling up to a million eggs which can be reintroduced to cattle through use of sewage effluent for irrigation of pastures, via infected feedlot workers with careless sanitation habits (although the egg cases are capable of independently forcing their way through the anal sphincter and would be dropped randomly) or by feeding contaminated water, hay, or sileage, or through birds and filth flies spreading the eggs which can pass through their bodies unharmed [96, p. 355]. The tapeworm eggs are fairly long lived--"71 days in liquid manure, 12 in city sewage, 76 in culinary water, 159 in cultivated pasture" [59, p. 203]. On uncultivated pasture, eggs have survived 2 years [82, p. 176].

Federal meat inspection is important in preventing cases of Taenia saginata in humans; as cattle do not show obvious signs of disease; there is no reliable test for detecting the disease in live animals; and there is no

TABLE 7: PATHWAYS OF HUMAN EXPOSURE TO TAPEWORM

I. Direct contact with live animal

- Animal bite
- Contact with the skin, fur, tail, etc. and microorganisms found there

II. Indirect contact with the live animal

- Aerosol contamination of the barn and air system (e.g. legionnaire's disease)
- Contamination of the walls, floor, gates, etc.
- Animal refuse (manure)
- Flies or fleas biting the infected animal and then biting humans and transmitting disease (malaria, bubonic plague)

III. Direct contamination by the carcass

- Some organisms penetrate the skin of personnel handling meat (e.g. toxoplasmosis and bovine leukemia virus)
- Entry of organisms through cuts and knicks on the hand of slaughterhouse or processing plant workers

IV. Indirect contamination by the carcass

- Aerosol contamination when the carcass is cut up and/or slapped on the counter, thereby releasing pathogens
- Contact with knives, wiping cloths, sinks, etc. where pathogens have been deposited

V. Cross contamination of other edible products

- Carcass contaminating other carcasses in the slaughterhouse
- Meat products in the processing plant
- Other raw or cooked foods in the kitchen or a private home or commercial feeding establishment

VI. Consumption of meat and meat products

practical treatment to rid cattle of T. saginata [124, pp. 8-9]. If there were, cattle could be routinely treated before being sent to market. Furthermore, the cysts are often microscopic and seldom larger than a quarter of an inch. 21/ Their white color may resemble fat. Grinding infected meat into hamburger can disguise the tiny white cysts containing the larvae. The presence of cysts would not adversely affect the returns of meat processors or retailers as consumers are not able to detect them in the meat. Similarly, as infected animals do not become obviously ill, the disease does not materially affect the farmer. Hence, little economic incentive exists to eliminate infected animals from the meat supply voluntarily.

However there have been three trends in farm management which do affect prevalence. The increased use of feedlots to raise beef increases the human/cattle interaction and increases the likelihood of disease in cattle. And the increased use of sewage effluent for irrigation of forage can increase animal exposure to the eggs. 22/ The increased use of indoor plumbing, though, decreases the chances for humans to contaminate cattle. Perhaps these trends offset each other, and the chances of cattle containing infective larvae if there had never been a Federal inspection program would be constant over time.

Again, as with the TB estimate, the most accurate technique of estimating the human health protection benefits is to compare the steady state with inspection vs. the steady state with never having had inspection. Again this is an "iffy" business. Given that there were opposing trends in farm management, I have assumed that without Federal inspection imposing a financial loss on sellers of "measly" beef (so called because a massive concentration of the white cysts containing the tapeworm larvae give a speckled or measly appearance to the beef) there would have been no reason to try to control Taenia saginata. Hence I assume that the prevalence in cattle would have remained unchanged at .028 percent. Applying this rate to the number currently inspected yields 9,380 carcasses with larvae (9,380 = .00028 times 33,627,730 inspected annually, 1977-81). A study of 20 condemned carcasses found an average of 370 cysts containing live larvae per animal, or a potential of 370 human tapeworms [62, p. 787]. The larvae were buried deep in muscles with a good blood supply and found throughout the carcass. Assuming that this carcass is cut up like the typical cattle carcass, around 17 percent of the meat

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21/ "Within 11 days the cysts measure 0.1 to 0.2 X 0.1 mm and in 70 days, when fully grown, 7 to 9 x 5 to 6 mm" [59, p. 204]. The maximum size, 9 millimeters, equals 35 percent of an inch, or 5/16 of an inch.

22/ "The ability of Taenia eggs to survive sewage treatment and be discharged with sewage effluent has been shown by a number of workers [104, p. 1714].

will be consumed rare 23/ and this rare meat will contain 63 viable larvae with the potential for causing 63 human infections (63 = .17 times 370). The number of human cases of tapeworm then is 591,000 annually (9,380 carcasses infected times 63 live larvae per carcass = 591,000 human cases of disease). 24/

It is assumed the human health protection benefit from inspection removing carcasses with Taenia saginata cysts containing viable larvae from the human food chain is the cost of treatment to rid the human of its tapeworm. This involves two visits to the doctor, a stool examination, and drugs, for a total of $50 per case [63]. If the two visits to the doctor require a half-day away from work, the productivity lost is $33 per case (4 hours x $8.25; the hourly wage rate in December 1981).

The total annual health cost avoided by eliminating 9,380 cysticercosis-infected carcasses from the food supply is $49 million assuming each carcass would have caused 63 human infections (9,380 carcasses times 63 larvae times $83 per human case of tapeworm = $49 million) (table 8).

An alternative measure of benefits is the immediate human health impact of ceasing inspection for Taenia saginata. There are two reasons why this estimate would not be very different:

1. Currently 10,000 cattle annually are found to harbor low levels of T. saginata infection. A slight relaxation of farm sanitation and vigilance could quickly turn these mild infections into severe infestations.

23/ Rib, sirloin and short loin steaks and roasts are approximately 25% of the boneless yields of a beef carcass [143, p. 17]. The remainder is round, flank, brisket, plate, and chuck cuts which would be cooked well done, except for the portion of these cuts turned into hamburger. Hamburger averages 26-28% of the utilization of the carcass. The 25% steaks and roasts plus the 27% hamburger adds up to 52% of the meat which is a candidate for rare consumption. If we assume 1/3 of these cuts are consumed rare, then 17% (.52 x .33 = .17) of the beef servings are eaten rare and thus would not be cooked at a temperature sufficient to kill Taenia saginata. Furthermore, if all the infected meat were ground into hamburger there would probably be a higher percentage cooked rare.

24/ Even with Federal meat inspection, tapeworm in humans is not unknown in the U.S. "In a recent survey of State Health Department laboratories, Taenia spp. were diagnosed at a rate of 23 per 10,000 fecal specimens. It is estimated that one-third of patients with taeniasis have never traveled outside the United States" and thus must have contracted tapeworm in the U.S. [96, p. 355].

TABLE 8: COSTS OF HUMAN INFECTION WITH <u>TAENIA SAGINATA</u> (TAPEWORM) AVOIDED BY MEAT INSPECTION

Type of Cost	Cost per Case	Estimate for 591,000 Human Cases
	------$------	--Million dollars--
Medical costs	50	29.6
Lost wages	33	19.5
Total	83	49.1

Note: Assumptions are 9,380 infected cattle carcasses would enter the human food chain annually and that each carcass would cause 63 human cases of tapeworm.

2. Given our modern large scale cattle-feeding industry, beef infected with <u>Taenia saginata</u> can be quickly spread through much of the U.S. from just one or two infected feedlots as shown by two case studies: In one case in an Arizona feedlot, 43% of the herd became infected and "if not detected by adequate meat inspection [would have presented] a health hazard to many thousands of people" [<u>82</u>, p. 169]. In the second case involving two commercial feedlots in the Texas panhandle, "within a 2-month period, 913 infected cattle were shipped for slaughter from these two establishments to widely separated areas of the United States" [<u>104</u>, p. 1708].

<u>Condemnations of Septicemic Carcasses</u>

One of the primary causes of condemnation of cattle carcasses under present federal slaughterhouse inspection is septicemic conditions. In the Food Safety and Inspection Service's (FSIS) annual statistical report there are two relevant categories: cattle carcasses condemned for septicemia and those condemned for abscess, pyemia. Question: Can these conditions be added together? I believe so since pyemia is defined as septicemia accompanied by multiple abscesses. In an animal with septicemia, the blood stream is invaded by a virulent microorganism and infection is spread throughout the whole body. Typically the animal experiences chills, fever, prostration, and often the formation of secondary abscesses in various organs. This infection is called blood poisoning in the popular jargon. FSIS inspectors removed from the human food chain an average of 17,695 septicemic cattle and 3,559 septicemic calf carcasses annually from 1977 to 1981. <u>25/</u>

<u>25/</u> Ideally we would like to know the change in the number of septicemic cattle entering the human food chain with, and then without, Federal inspection. It may be that the actual number of condemnations is too low a number because currently some animals may be screened and held back from shipping to the slaughterhouse because there is a high probability of condemnation by Federal inspectors; and thus in the absence of Federal inspection more septicemic cattle would enter the slaughterhouse. On the other hand it may be that the actual number of condemnations without Federal inspection might not increase as much as would be anticipated because either State or industry self-regulation in the absence of Federal inspection could result in approximately the same number of removals.

Unfortunately laboratory analyses of these condemned carcasses are not done to identify the organism causing the septicemic condition of the animal. However, another data source is available; the American Veterinary Medical Data Program which computerizes the medical records of animals brought to the clinics or hospitals of the participating veterinary colleges. Escherichia coli was identified as the causative organism in 58% of the 257 septicemic cattle examined during 1974-79. 26/ Can it be safely assumed that the causes of septicemia are the same for beef and dairy cattle seen at the 15 veterinary schools putting their data into this computer as for beef and dairy cattle moving through commercial channels? 27/ Can it be then assumed that 58% of the septicemic cattle condemned by Federal inspectors are suffering from E. coli invasion of the blood stream?

The Animal/Human Disease Linkage. It is known that strains of E. coli in cattle and calves can cause human disease and human volunteers have become ill after ingesting E. coli strains from both animal and human origins [96, pp. 219-221]. A survey of 400 calves from separate farms located over a wide area of England and Wales identified 94 E. coli strains [56, p. 317]. Other researchers have determined that 36 of these 94 strains have been implicated in human disease encompassing a wide clinical spectrum ranging from severe diarrhea to cholera-like illnesses to fatal septicemic infections [100, p. 334]. (See appendix D for further identification of serotypes.) The people affected included essentially all age groups from the nursery to geriatric populations. E. coli can cause human disease by at least two types of mechanisms: (1) production of toxins or (2) E. coli penetration

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27/ The remaining 42% of the septicemic beef or dairy cattle had unidentified or wide ranging causative organisms: Clostridium perfringens infection, pneumonia caused by Salmonella, anaphylaxis, streptococcus, and pasteurellosis to name a few of the diagnostic conditions and/or organisms [1].

28/ The veterinary medical colleges see both dairy and beef, cattle, however their average age may be greater than the average age of cattle sent from the feedlots to the slaughterhouse. Evidence for younger animals, however, indicates that E. coli is common and the primary cause of calf diarrhea called calf scours:

> "Due to the ubiquitous nature of Escherichia coli, there has been some question as to whether it is a secondary invader or the primary pathogen. It is now generally believed that the condition [white scours of calves] is produced by certain serotypes of E. coli" [75, p. 47].

And Amstutz states:

> "I believe that E. coli is responsible for more than 90% of the cases of infectious calf diarrhea in midwestern United States, that S. typhimurium causes approximately 5%, and that other microorganisms are responsible for the remainder" [3, p. 690].

of the intestines and absorption into the blood stream which enables it to move throughout the body and invade other organs and create abscesses. 28/ (See table 9 for the pathways E. coli can can use to infect humans).

The Infective Dose. Studies with human volunteers have shown that ingestion of 10^6 to 10^{11} E. coli cells is sufficient to colonize the human intestinal tract [96, pp. 218-221]. This colonization may last for a few days to several months. Ingestion of both animal and human serotypes resulted in the volunteers having typical disease symptoms. Generally, the greater the numbers of E. coli ingested, the more severe the illness.

Given that the septicemic animal has the pathogens in the circulatory system, contamination of all the meat tissue appears probable [117 pp. 604-605]. Thus the E. coli appear to be spread throughout the body and it seems likely that an infective dose could occur in a typical 3 ounce serving of septicemic meat, unless the invasive E. coli were destroyed by cooking the meat well done.

Cross Contamination. Not only do we need to examine the potential human health risk of consumption of septicemic meat which has been grossly contaminated with E. coli, but we also need to examine the possibilities of cross contamination from this meat to other meat in the slaughterhouse, the processing plant, and of other foods in the home. E. coli has been found to be widespread in the slaughterhouse where it has been found on

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28/ "Certain strains of E. coli can cause enteric disease in man, either by elaborating a cholera-like enterotoxin or by penetrating the intestinal epithelium as Shigella does. Enterotoxigenic strains cause mild to severe diarrhea (rice-water stools) with profound dehydration and shock without fever. The diarrhea usually ceases within 30 hours. When studied in human volunteers, illness of the toxigenic type developed 8 to 44 hours (mean 26 hours) after challenge with 10^{10} cells. Enterotoxigenic strains colonize the upper gut and elaborate an enterotoxin. This toxin exerts its effect on epithelial cells, causing secretion of salt and water into the lumen, which results in diarrhea. During the patient's recovery, toxigenic strains are cleared from the small bowel. They can continue to colonize the large intestine, but they cause no effect on the mucosa of the large intestine. The patient remains an asymptomatic carrier, however, as long as these organisms stay in the large bowel.

Invasive strains cause a febrile illness with chills, fever as high as 40°C, headache, myalgia, abdominal cramps, and profuse watery diarrhea. The invasive strains can also cause hypertension, systemic toxemia, and tenesmus; the feces sometimes contain blood, mucus, and abnormal numbers of epithelial cells. When studied in human volunteers, illness of the invasive type developed in 8 to 24 hours (mean 11 hours) after challenge with 10^8 cells" [96, pp. 218-219].

TABLE 9: PATHWAYS OF HUMAN EXPOSURE TO E. COLI SEPTICEMIA

I. Direct contact with live animal

- Animal bite
- Contact with the skin, fur, tail, etc. and microorganisms found there

II. Indirect contact with the live animal

- Aerosol contamination of the barn and air system (e.g. legionnaire's disease)
- Contamination of the walls, floor, gates, etc.
- Animal refuse (manure)
- Flies or fleas biting the infected animal and then biting humans and transmitting disease (malaria, bubonic plague)

III. Direct contamination by the carcass

- Some organisms penetrate the skin of personnel handling meat (e.g. toxoplasmosis and bovine leukemia virus)
- Entry of organism through cuts and knicks on the hand of slaughterhouse or processing plant workers

IV. Indirect contamination by the carcass

- Aerosol contamination when the carcass is cut up and/or slapped on the counter, thereby releasing pathogens
- Contact with knives, wiping cloths, sinks, etc. where pathogens have been deposited

V. Cross contamination of other edible products

- Carcass contaminating other carcasses in the slaughterhouse
- Meat products in the processing plant
- Other raw or cooked foods in the kitchem or a private home or commercial feeding establishments

VI. Consumption of meat and meat products

the floor, instruments, sinks, as well as the meat at all stages in preparation. Thus E. coli survive in the slaughterhouse environment. Furthermore, "serotyping suggested that there was a considerable interchange of E. coli between carcasses" [107, p. 227]. E. coli are frequently found on the hands and under the fingernails of food handlers and butchers. 29/

Researchers also believe that "E. coli can be and are transferred on many occasions by the hands from raw to raw and from raw to cooked or processed foods" in the kitchen of a hospital, restaurant or home [92, p. 680]. Researchers in Maine routinely examining ground beef have noticed an increase in contamination during the past 20 years and now most hamburger contains coliforms, including E. coli:

> "During the middle 1950's through middle 1960's if one purchased ground beef from a reputable source the samples were usually free from or low in coliforms. From the mid 1960's to the present time, with all the modern facilities used for processing ground beef, the microbial flora has changed and most of the samples contain coliforms. The total count has also increased materially. Recent studies indicate that between 80 and 100% of the ground meat samples contain coliforms and 50% contain Salmonella species [16, p. 1]."

Obviously, if there were no federal meat inspection removing septicemic carcasses from the human food chain, then the problem of slaughterhouse contamination with E. coli and contamination of the meat would be much more severe. Diarrhea is not commonly associated with meats in the public mind. However, a large number of such cases in the 1880's in New York City prompted veterinarians to set up the first public health system in the New York City health department [105].

Bryan, Ayres and Kraft found that cross-contamination during processing in a turkey plant more than doubled the percentage of

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29/ Horwood and Minch in their 1951 study of 34 food handlers found E. coli on 12 (38%) of the hands tested [55]. Pether and Gilbert isolated E. coli from the fingertips of 13 (12%) of the 110 butchers soon after leaving duty and state "the difference in the isolation rates of E. coli is probably attributable to the fact that the butchers hands are continuously exposed to contamination from the meat they are handling. The isolation rates from the butchers would probably have been much higher if a finger rinse technique would have been used instead of the finger impression technique and if sampling had been done immediately after the butchers had left the meat line [92, p. 679]. And another study of calves suffering from septicemia, 77 strains of E. coli were isolated from the air, wall and floor surfaces, overalls and hands of caretakers [6].

samples contaminated with salmonellae: "These organisms were isolated from swab samples from 12 percent of chilled, eviscerated turkey carcasses, 27 percent of finished products, and 24 percent of processing equipment" [15, p. 1]. A study in Holland of sixty families preparing a frozen chicken contaminated with E. coli K_{12} found that "In a number of kitchens, after rinsing and washing-up, the cutting board, sink or dishcloth were still contaminated 30/... it can be concluded that a cross-contamination with E. coli K_{12} could easily occur in these kitchens. The organisms survived for a long period on various surfaces in the kitchen, so that the fried chicken or other food could be contaminated again" [30, p. 30]. I believe that assuming cross-contamination will double the number of human cases of disease is a conservative estimate for E. coli, particularly since it persists in the slaughterhouse and kitchen. Cross-contamination then doubles the total number of potential cases of human infection.

Benefit Estimation. Estimation of the total benefits gained by avoidance of human disease through consumption of septicemic meat contaminated with E. coli or human contact requires a series of assumptions, and it is these assumptions that determine whether or not the estimated results are reasonable. An average of 17,695 cattle and 3,559 calves were condemned for septicemia annually from 1977-1981. Ideally we would like to have data on the organisms responsible for disease in the condemned animals. But these animals are not sampled for microbiological assessment. Consequently, our only alternative is to use a substitute data source. The American Veterinary Medical Data Program provides a much smaller sample of animals, but does identify the causes of septicemia in beef and dairy cattle examined at clinics and hospitals of the veterinary schools. This sample's findings should be similar to those which would be found with a corresponding examination of commercial cattle entering the slaughterhouses.

In the veterinary schools, E. coli caused 58 percent of the cases of septicemia and if this ratio is applied to carcass condemnations for septicemia, then 10,263 cattle carcasses and 2,064 calf carcasses contaminated with E. coli are removed annually from the human food chain.

By using some typical conversion ratios shown in table 10, I estimate the servings of meat from a carcass that actually reaches the dinner table. The average cattle carcass yields 1,380 servings and the average calf carcass yields 395 servings. 31/

30/ After rinsing, 77 percent of the cutting boards and 72 percent of the other items (plate, dish, strainer, etc.) sampled were contaminated [30, p. 29].

31/ I assumed that, on average, each serving is eaten by different individuals. In reality, some servings may be used in casseroles or other dishes where several people would share the serving of meat and all could potentially contract disease. In other cases a family might buy a roast or multiple servings of hamburger and serve the same food a couple of nights in a row so that the same individuals would be exposed to the same health hazard on consecutive day.

TABLE 10: AVERAGE NUMBER OF SERVINGS OF MEAT PER CALF OR CATTLE CARCASS AND THE ANNUAL NUMBER OF SERVINGS POTENTIALLY CONTAMINATED WITH E. COLI FROM SEPTICEMIC CARCASSES

		Beef/ Cattle	Veal/ Calves
a.	Ratio of dressed weight to live weight	.59	.56
b.	Ratio of retail weight to dressed weight	.74	.83
c.	Ratio of cooked weight to retail weight	.62	.69
d.	= a x b x c Percent of carcass live weight reaching the dinner table as lean and fat (no bone)	.27	.32
e.	Average carcass live weight (pounds)	1,024	247
f.	= d x e Cooked weight or lean and fat on the dinner table (pounds)	276	79
g.	Number of servings per pound of cooked fat and lean	5	5
h.	= f x g Number of servings per animal	1,380	395
i.	Number of animals condemned for septicemia annually, 1977-1981	17,695	3,559
j.	= h x i Number of servings of meat potentially contaminated with E. coli	24,419,100	1,405,805

Sources: (a), (b), and (e) from [143, pp. 6 and 16].
(c) from [154, p. 31].
(g) from [42] showing about 10% of meat ends up as plate waste and [154] showing a cooked serving of meat is slightly less than 3 oz.
(i) [153, 1977-1981.]

The next consideration is whether the pathogens would be destroyed during processing or by cooking. Pickling the meat by turning it into corned beef does not eliminate E. coli or other pathogens. Dempster, Reidy and Cody reported that "curing brines used in retail shops and supermarkets to produce corned beef were a potent source of contamination" [29, p. 815]. Freezing is also not a panacea. Mackey, Derrick and Thomas reported that E. coli cells frozen on beef at -20°C declined "only slightly in seven months and few survivors were injured" [79, p. 322]. At -5°C E. coli destruction was greater: "viability declined more rapidly and over 90% of survivors were injured after five months" [Ibid].

Furthermore, E. coli contamination of hamburgers increases during refrigerated storage (Table 11). Kotula et al purchased four samples each from three meat wholesale distributors and reported the following increase in coliforms for up to 12 days of refrigeration which is the maximum storage time for patties "normally...presented to consumers" [69, p. 56].

TABLE 11: MEAN COLIFORM COUNT PER GRAM OF UNCOOKED BEEF PATTIES FROM THREE MEAT WHOLESALE DISTRIBUTORS 1/

Days of Refrigerator Storage (4°C or 39°F)	Distributor		
	1	2	3
1	2,400	500	1,700
5	9,200	1,400	180,000
12	1,800,000	1,400,000	320,000

1/ To translate these numbers to a per serving basis, multiply by 114. (The typical cooked hamburger serving is three ounces, or four ounces uncooked, and there are 28.4 grams in an ounce (4 x 28.4 = 114).

By the fifth day, the average of the four samples from distributor 3 contained an infective dose (10^6 organisms) if consumed raw and distributor 1 was borderline infective. By day twelve, samples from all distributors were infective. The counts of E. coli in septicemic meat would start at an infective dose and increase to higher levels during marketing and home storage.

Cooking destroys E. coli, although they are "not completely destroyed until the meat is cooked well done. The greater the initial load of E. coli the longer the cooking time to kill all of them" [16, p. 6]. And even well done frozen or partially defrosted hamburger patties may have "little or no visible change in the coloration of the center meat" [122, p. 473]. In beef consumed rare, invasive E. coli pathogens would survive [16, p. 6]. It is assumed that 17 percent of a beef carcass is consumed rare--half as hamburgers and half as steaks and high quality roasts. Cooking would destroy E. coli in the remaining 83 percent of the potentially infective servings, further reducing the potential cases of human illness.

E. coli can cause a variety of diseases in humans ranging from severe diarrhea to urinary tract infections to fatal septicemia. E. coli is one of the "commonly encountered pathogens" causing septicemia in humans [6, p. 5]. The data on which strains of E. coli cause which types of disease are unclear. Consequently, there does not appear to be agreement among microbiologists about how to classify and serotype E. coli according to a schema relevant for human disease consequences. Perhaps the diverse disease outcomes of serotypes is because plasmids are linked with disease and these plasmids can be transferred among serotypes [115, p. 103].

While clearly there is a relationship between animal and human diseases caused by strains of E. coli, that relationship is not readily quantifiable. The data in appendix D indicate that of 94 E. coli O-serotypes found in healthy cattle and calves, 36 are capable of being pathogenic to humans--yet this information is not a full catalogue of E. coli serotypes and furthermore does not tell us anything about the distribution of serotypes among cattle and calves condemned for septicemia. Nevertheless, if one conjectures that this ratio (36/94) of human pathogenicity would apply to the inspected septicemic carcasses, then 38 percent of the E. coli strains causing septicemia in cattle and calves would also cause human disease. 31/ This is the weakest link in the analysis. There is no way of knowing whether or not the 38 percent assumption is reasonable. In fact, future research may find that while the cattle/calf and human strains have the same O-serotype, pathogenicity may be caused by untested properties that may differ among humans vs. cattle and calves. If this were found to be true, it may be that there is no disease crossover from cattle to humans and eating septicemic meat would not cause human disease. The lower bound of our range then assumes a zero probability of human infection; and the upper bound is a 38 percent likelihood of human infection.

Then the question becomes: "What kind of human illnes?" Diarrhea is the least serious disease outcome and is used to develop the "cost of illness" avoided by inspection for septicemic cattle and calf carcasses. A study by the Centers for Disease Control (CDC) in Atlanta estimated that the average per person cost of diarrhea caused by salmonellae in a Colorado outbreak was $646 in 1976 (table 12). Assuming that the diarrhea caused by E. coli affects people similarly and updating the costs to

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32/ An Indian study of animals (cows, calves, buffaloes, buffalo-calves, goats and kids) with sporadic cases of gastroenteritis identified 153 strains of E. coli. These strains fell into 38 "O" groups: 7 pathogenic to humans as well as animals and 31 pathogenic only to animals. "The proportion of human pathogenic "O" groups isolated from cows and calves was the highest," 5 out of 13 or 38 percent [174, pp. 200, 203].

TABLE 12: POTENTIAL-RELATED COSTS ASSOCIATED WITH DIARRHEA

	Average Cost Per Person	
	1976 prices	Updated to 12/81 prices a/
Medical costs, total	$ 441.88	$ 740.00
Physician office fee	39.03	
Emergency room	16.88	
Medication	9.56	
Hospitalization	376.41	
Income or productivity loss	170.24	254.00
Miscellaneous	33.71	56.00
Total	645.83	1,050.00

a/ Not all persons incurred costs in each category, thus the average costs are below those actually incurred by an individual since costs are averaged over the total number of cases.

The 1981 prices adjusted upward using indexes published by the Bureau of Labor Statistics. The medical costs are updated using the December 1981 medical care component in the Consumer Price Index (CPI) compared to its 1976 value. The income or productivity loss are updated by the December 1981 gross weekly earning for private workers compared to the 1976 value. The miscellaneous value is updated using the all items CPI values.

Source: [21]

December 1981 dollars, medical costs would average $740 per case, costs which are dominated by the costs of hospitalization for the 29 percent of those ill who are hospitalized. The income or productivity loss average $254 per case. The total cost per case (which includes miscellaneous items) is $1,050.

Conclusion. The relationship between animal and human disease is not thoroughly researched for the numerous strains of E. coli, and even more basic is the lack of consensus on the relevance of serotyping or identification of plasmids to disease. Nevertheless, I did attempt to estimate the human health outcome from consumption of domestically produced beef that would enter the human food chain in the absence of Federal Meat Inspection for septicemia.

First, it was assumed that the septicemia was caused by E. coli 58 percent of the time (table 13). Second, the type of E. coli causing septicemia in beef animals could also cause human disease from an assumed 38 percent of the time (high estimate) to zero percent of the time (low estimate). The third assumption is that 83 percent of the time the meat would be so well cooked as to destroy the E. coli and that the pathogens would survive in an infective dose only 17 percent of the time. Multiplying these three factors together yields a probability of human infection for the high estimate of 3.7 percent [0.03747 = (58 percent) x (38 percent) x (17 percent)]. The annual number of beef and veal servings removed from the human food chain for septicemia total 25.8 million which is doubled by cross-contamination to 51.6 million servings. Multiplied by the 0-3.7 percent incidence of human illness yields an estimate of 0 to 1.9 million cases of human illness annually. The cost per case was estimated as $1,050 (table 12) and yields an estimate of 0 to $2.0 billion (for the annual cost of illness avoided). Given the tenuous and tentative nature of the estimates, the only clear message to administrators and researchers is: "collect more data and develop more extensive and reliable data series," for example, more laboratory research with respect to disease transmission between animals and humans.

TABLE 13: SUMMARY OF ESTIMATED BENEFITS FOR REMOVAL OF SEPTICEMIC BEEF FROM THE HUMAN FOOD CHAIN

	ASSUMPTIONS	ESTIMATES
I.	Number of animals afflicted and cross-contamination likely	Cattle and calves currently condemned for septicemia would be 25.8 million servings of meat if allowed to enter the human food chain. Cross-contamination doubles the cases of human illness.
II.	Causative organism	_E. coli_ in 58% of septicemic cattle at veterinary colleges
III.	Animal/human disease linkage, i.e. likelihood that the animal pathogen is also a human pathogen	Range of 0-38% based on suggestive, but insufficient studies
IV.	The infective dose when contact occurs directly or indirectly in each of the possible ways	Contained in 100% of servings-- 10^6-10^{11} pathogens needed and would be found in each septicemic serving
V.	The effect of cooking or other types of processing and preparation on the likelihood of pathogen survival	17% of meat is cooked rare and would contain pathogens
VI.	Likelihood of humans becoming ill through consumption of meat, contact with the animal, etc.	VI = II x III x IV x V. 0-3.7% persons eating septicemic meat would become ill
VII. VIII.	Costs of medical treament Wages or productivity lost through illness or death	Least severe illness is diarrhea and a salomonella outbreak causing diarrhea costs $1,050 in current dollars per person
IX.	Unmeasurable unmonetizable costs such as the pain or suffering of ill person as well as pain and suffering of third parties such as spouses	No estimate made

SUMMARY

These three diseases were chosen for a number of reasons (Table 14). First, scanty as the epidemiologial linkages may seem, these diseases were the easiest to make linkages from animals to humans which meant that the inspection reporting form had to list the condition as a separate category and that the scientific data were sufficiently rich. Second, all three disease conditions are, or were, important in terms of their prevalence in animals. Third, each represents a different type of human health hazard. Tuberculosis is caused by a bacterium and is transmitted through the air from the live animal or its carcass to farm families, slaughterhouse workers or processing plant workers. Taenia saginata is a parasite and human tapeworm infections come from eating a live larva imbedded in muscle tissue. Septicemia caused by E. coli, another bacterium, probably can be transmitted to humans through consumption, contact, cross-contamination of other foods, etc. The epidemiology is still sketchy and the pathogenic characteristics of E. coli are not well understood. Last, none of the three animal diseases are easily preventable...while we can treat TB and tapeworm in humans, there is no effective treatment or vaccine for cattle. (While some new vaccines for calf scours caused by E. coli have been marketed in the last couple of years, it is not clear whether the vaccine would have any effect on the E. coli causing septicemia.)

Because of the wide range of the estimates, definitive conclusions about the cost effectiveness of the present meat inspection system, costing somewhat over 300 million Federal dollars, cannot be drawn. However, the data do suggest that some Federal effort is cost effective:

- There are a wide variety of viral, bacterial and parasitic infections that are common to animals and humans and can probably be transmitted from food animals to humans (appendix A),

- The multiple stages required to prepare meat for retail sales, and the inability to consumers to individually identify meat and poultry products that are free of infectious or toxic agents together provide the opportunity to compromise product quality, an opportunity particularly attrative when costs must be cut.

- The high and the low estimates for just these three diseases do bracket the total costs of the Federal inspection program, which suggests a more complete accounting of the human disease prevention consequences of Federal inspection would be significantly greater than program costs.

There are three types of limitations of the research findings in this paper. First, as has been discussed throughout the paper, the scientific data base is still being developed on epidemiology and what characteristics of what organisms are pathogenic to humans and animals under what conditions.
Some of the data are excellent while other data are still in the

TABLE 14: PARTIAL ESTIMATION OF BENEFITS OF FEDERAL MEAT INSPECTION

Source	Low	High
	Million dollars	
Human diseases avoided:		
Tuberculosis	16.4	154.6
Beef tapeworms	49.1	49.1
E. coli diseases	0	2,000.0
Total	65.5	2,203.7

formative or discovery phase which makes it difficult to quantify the human health risk of diseased or contaminated animals.

Second, benefit/cost analysis itself has limitations. This application requires "guesstimating" what would have occurred if the program had never been implemented. We are comparing an actual state of the world with a hypothetical one. In this paper I estimated the incidence of cattle with tuberculosis and tapeworm larvae that would have entered the human food chain in the absence of Federal meat inspection.

Further, benefit/cost analysis tries to measure things and unmeasurable items such as the pain and suffering of the ill persons are left out, thus the estimates are underestimates. However, unmeasurable things can be catalogued and the reader left to gauge their importance.

Third, this analytical effort only examines three diseases. Other actual or hypothetical inspection procedures are not evaluated to see if they would have higher human health protection benefits. This report is not an overview of the whole meat and poultry inspection program, but only a partial examination. Also, the impact on the industry has not been discussed. While inspection may reduce disease and thereby increase the overall healthfulness of the animals, the inspection process itself may impose costs on the industry such as carcass condemnations or reducing the flexibility of plant hours and procedures. We know industry reimbursements to FSIS for inspector overtime. In 1967, reimbursements were $14 million; in 1974, $23 million; in 1978, $26 million; in 1979, $31 million and in FY 1982, $33 million [4]. Another consideration is that the public confidence in the healthfulness of meat is probably enhanced by inspection and thus meat consumption is higher than otherwise. How these forces balance out is a question that remains to be addressed.

APPENDIX A: DISEASES COMMUNICABLE FROM ANIMALS TO HUMANS

Infection	Agent	Mode of transmission	Common non-human vertebrate hosts	Prevalence in man	Seriousness of infection in man
Viral infections					
Contagious ecthyma	Virus	Contact	Sheep	Sporadic	Mild
Cowpox and pseudocowpox	Viruses	Contact	Cattle	Common	Mild
Encephalomyocarditis	Picorna virus	Vehicle	Rodents, swine, primates	Sporadic	Serious
Foot-and-mouth disease	Picorna virus	Contact	Sheep, cattle, swine, wild mammals	Sporadic	Mild
Influenza and parainfluenza	Type A influenza virus	Contact	Swine, fowl, horses	Common	Serious
	Type D influenza virus (Sendai)	Contact	Rodents		
Lymphocytic choriomeningitis	Virus		Rodents	Sporadic	Serious
Newcastle disease	Virus	Contact	Fowl, wild birds	Sporadic	Mild
Psittacosis-ornithosis	Bedsonia virus	Contact	Fowl, wild birds	Sporadic	Sometimes fatal, usually mild
Rabies	Virus	Contact	Dogs, wild mammals	Sporadic	Fatal
Simian herpes (B virus)	Virus	Contact	Primates	Sporadic	Serious
Vesicular stomatitis†	Virus	Contact and mechanical vector	Cattle, horses, swine	Sporadic	Usually mild
Catscratch fever	Virus (?)	Contact (?)	Cats	Common	Mild
Smallpox*	Virus	Contact	Primates	Sporadic, common locally	High mortality
Poliomyelitis*	Virus	Vehicle	Primates	Common	Usually mild
Salivary gland virus	Virus	Contact (?)	Monkeys, rodents	Sporadic	May be serious
Respiratory syncytial infection (chimpanzee coryza)	Virus	Contact	Primates	Common	Mild
Pseudorabies	Virus	Contact (?)	Swine, rodents, cattle, sheep	Rare	
Reovirus infection	Reovirus	Contact	Primates, cattle	Sporadic	Mild
Rickettsial infections					
Q fever†	*Coxiella burnetti*	Vehicle, contact	Sheep, cattle, wild mammals	Common	Serious

Infection	Agent	Mode of transmission	Common non-human vertebrate hosts	Prevalence in man	Seriousness of infection in man
Bacterial infections					
Anthrax	*Bacillus anthracis*	Contact	Cattle, horses, swine, sheep	Sporadic	High mortality
Brucellosis	*Brucella abortus*	Vehicle, contact	Cattle, sheep	Sporadic	Serious
	B. melitensis	Vehicle, contact	Sheep, goats	Sporadic	Serious
	B. suis	Vehicle, contact	Swine	Sporadic	Serious
Salmonellosis	*Salmonella* spp.	Vehicle	Fowl, rodents, swine, poikilotherms	Common	Serious
Staphylococcosis	*Staphylococcus* spp.	Vehicle, contact	Dogs, other animals	Common	Serious
Streptococcosis	*Streptococcus* spp.	Vehicle, contact	Cattle, dogs	Common	Serious
Colibacillosis	*Escherichia* spp.	Vehicle	Cattle, swine	Common	Serious
Erysipeloid‡	*Erysipelothrix insidiosa*	Contact	Swine, fowl, fish (?)	Sporadic	Serious
Glanders	*Actinobacillus mallei*	Contact	Horses	Sporadic	Serious
Leptospirosis	*Leptospira* spp.	Vehicle, contact	Dogs, cattle, rodents	Sporadic	Serious
Listeriosis‡	*Listeria monocytogenes*	(?)	Cattle, sheep, fowl	Sporadic	High mortality
Klebsiella infection*	*Klebsiella pneumoniae*	Contact	Cattle, dogs	Common	Serious
Melioidosis	*Pseudomonas pseudomallei*	Vehicle, contact	Rodents	Sporadic	Serious
Pasteurellosis	*Pasteurella multocida*	Contact	Cattle, horses, sheep, swine, dogs, cats	Sporadic	Serious
Pseudotuberculosis	*Pasturella pseudotuberculosis*	Contact	Rodents	Sporadic	Serious
Rat-bite fever	*Spirillum minus*	Contact	Rodents	Sporadic	Serious
	Streptobacillus moniliformis	Contact	Rodents	Sporadic	Serious
Tuberculosis	*Mycobacterium tuberculosis bovis*	Vehicle, contact	Cattle	Common	Serious
	*M. t. hominis**	Vehicle, contact	Cattle, dogs	Common	Serious
	M. t. avium	Vehicle, contact	Fowl, swine	Sporadic	Serious
Tularemia†	*Francisella tularensis*	Contact	Wild mammals	Sporadic	Serious
Vibriosis	*Vibrio fetus*		Cattle	Sporadic	Serious
Tetanus	*Clostridium tetani*	Vehicle	Horses	Common	High mortality
Bacillary dysentery*	*Shigella* spp.	Vehicle	Dogs	Common	Serious
Diphtheria*	*Corynebacterium diphtheriae*	Vehicle		Common	Sometimes serious, usually mild
Fungal infections					
Ringworm	*Microsporum* spp.	Contact	Dog, cat	Common	Serious
	Trichophyton spp.	Contact	Cattle, horse	Common	Serious
Candidiasis*	*Candida albicans*	Contact	Fowl	Common	Serious

Infection	Agent	Mode of transmission	Common non-human vertebrate hosts	Prevalence in man	Seriousness of infection in man
Protozoal infections					
Balantidiasis	*Balantidium coli*	Vehicle	Swine	Sporadic	Serious
Amebiasis*	*Entamoeba histolytica*	Vehicle	Dog, monkey	Common	Sometimes serious, usually mild
Toxoplasmosis	*Toxoplasma gondii*	(?)	Mammals	Common	Sometimes serious, usually mild
Nosemosis	*Encephalitozoon* (*Nosema*) *cuniculi*	(?)	Rodents	Rare	Serious
Pneumocystis infection	*Pneumocystis carinii*	(?)	Dogs	Locally common	Serious
Sarcosporidiosis	*Sarcocystis* spp.	(?)	Cattle, rodents, wild birds	Sporadic	No disease
Giardiasis	*Giardia lamblia*	Vehicle	Primates	Sporadic	Sometimes serious
Iodamoeba infection	*Iodamoeba bütchlii*	Vehicle	Primates, swine	Sporadic	No disease
Cestode infections					
Hymenolepiasis	*Hymenolepis nana*†	Vehicle	Rodents	Common	Mild
Nematode infections					
Trichinosis	*Trichinella spiralis*	Vehicle	Swine, rodents, foxes, dogs, other wild animals	Sporadic	Serious
Arthropod infestations					
Scabies	*Sarcoptes scabei* (other mites)	Contact	Horse	Sporadic	Sometimes serious

* Organism isolated from other species, but present evidence suggests that man is the sole or most important reservoir of human infection.

† Also a meta-zoonosis.

‡ Possibly also a sapro-zoonosis.

SOURCE: [106, pp. 232-35. Permission for reproduction granted by Williams & Wilkins Co., Baltimore, Maryland].

APPENDIX B: AGE DISTRIBUTION OF 10,000 DEATHS AND PRESENT VALUE (PV) OF LIFETIME EARNINGS AND HOUSEKEEPING SERVICES DISCOUNTED AT 10% FOR 1977 AND 1981

AGE	MEN			WOMEN		
	Number	PV 1/		Number	PV	
		----------$000----------			----------$000----------	
0-4	39	50.6	1,973.4	24	44.2	1,061.0
5-14	12	91.6	1,099.2	9	80.0	720.1
15-24	51	172.9	8,817.9	33	138.5	4,570.8
25-44	609	213.3	129,899.7	321	137.2	44,055.0
45-64	2,437	108.7	264,932.4	1,041	83.1	86,524.8
65 +	3,651	7.8	28,322.3	1,773	23.6	41,874.7

GRAND TOTAL: $613,851,300 for 10,000 cases
Average loss per death in 1977 dollars = $61,400
Average loss per death in 1981 dollars = $92,000

1/ Standard human capital estimates based on the present value of both expected lifetime earnings and housekeeping services; a real discount rate of 10 percent; and an annual increase in labor productivity of 1 percent.

*Adjusted by the percentage increase in the CPI (Consumer Price Index) for 1981 vs. 1977.

Sources: [31, 71, 156].

APPENDIX C: AGE DISTRIBUTION OF 10,000 DEATHS AND THE ALTERNATIVE ESTIMATE OF THE VALUE OF LIFE, 1977 AND 1981 DOLLARS

AGE	MEN			WOMEN		
	Number 1/	PV 2/		Number 1/	PV 2/	
		---------$000---------			---------$000---------	
0-4	39	695.4	27,121	24	475.3	11,407
5-14	12	810.5	9,726	9	553.3	4,980
15-24	51	952.6	48,583	33	625.2	20,632
25-44	609	824.5	502,121	321	498.3	159,954
45-64	2,437	315.6	769,117	1,041	235.9	245,572
65 +	3,651	19.4	70,829	1,773	52.1	92,373

GRAND TOTAL: $1,962,415,000 loss for 10,000 deaths
Average loss per death in 1977 dollars = $196,242
*Average loss per death in 1981 dollars = $294,363

1/ [156]
2/ Adjusted willingness-to-pay human capital estimates based on the present value of both expected lifetime after-tax income and housekeeping services (where income is estimated from earnings by using the ratio of disposable income to wages and salaries equal to 1.33), an after-tax real rate of return equal to 3 percent; an annual increase in labor productivity of 1 percent; and a risk-aversion premium of 1.6. [71]

* Adjusted by the percentage increase in the CPI (Consumer Price Index) for 1981 vs. 1977.

APPENDIX D: E. COLI O-ANTIGEN TYPES FROM CALVES AND WHETHER THEY HAVE CAUSED HUMAN DISEASE

Calf O-type	Human Disease				
	Unspecified Illness	Diarrhea		Invasive	
		Infant	Adult	Dysentery	Septicemia
1	yes				yes
2	yes				yes
3					
4					yes
5					
6	yes	yes	yes		yes
7	yes				yes
8	yes		yes		
9	yes				yes
10	yes				
11	yes		yes		yes
12					
13					
15	yes		yes		yes
16	yes				
17	yes				
18					yes
20		yes	yes		
21					
22					yes
23		yes			
24					
25			yes	yes	yes
26	yes	yes			
30					
32					
34					
35					
36					
40					
43					
44	yes				
45					
46					
49					
50	yes				
51					
54					
61					
65					
68					
70					
73					
74					
75	yes				yes

Calf O-type	Human Disease				
	Unspecified	Diarrhea		Invasive	
	Illness	Infant	Adult	Dysentery	Septicemia
76					
77					
78	yes		yes		yes
80					
82					
83					
84					
86	yes	yes			
88					
89					
90					
91					
99					
101	yes				
102					
103					
104					
105					
107					
108					
109					
110					
111	yes	yes			
113					
114		yes			
115	yes			yes	
117					
118	yes				
119		yes			
120					
121					
123					
124	yes		yes	yes	
125	yes	yes			
126	yes	yes			
127	yes	yes			
128	yes	yes	yes		
131					
132					
134					
135					
138					
141					
143				yes	
144				yes	
145					
146					
149			yes		
153					

Source: [56, p. 324; 93, p. 791; 96, pp. 218-19; 86, p. 204; 117, p. 606, 92, p. 631].

APPENDIX E: THE LETHALITY FOR CHICKENS AND MICE OF BACTEREMIC STRAINS OF *E. COLI* FROM DIFFERENT SOURCES

Source of *E. coli*	Number of Strains Tested	Number Lethal for *	
		Chickens	Mice
Human **	45	27	36
Chicken	40	39	—
Calves and Lambs	14	13	—
Total	99	79	36

* Chickens received 0.3 ml volumes of a broth culture intravenously and mice 0.05 ml intraperitoneally.

** Bacteremia or meningitis.

Source: [<u>115</u>, p. 98].

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