

# **An Impossible Undertaking: The Eradication of Bovine Tuberculosis in the United States**

**Alan L. Olmstead and Paul W. Rhode**

February 2003

**Abstract:** In 1900 bovine tuberculosis represented a growing threat to both animal and human health. In 1917, shortly after a series of scientific breakthroughs allowed the early detection of TB in cattle, the USDA embarked on a national campaign to eradicate the disease. This was a wholly unprecedented and highly controversial effort, with state and federal agents inspecting nearly every cattle farm in the country, testing the animals, and condemning nearly 4 million reactors to slaughter without full compensation. This paper analyses how the eradication program functioned, how incentives were aligned to insure widespread participation without excessive moral hazard problems, and why the US led most European nations in controlling the disease. The US campaign was a spectacular success. For the farm sector alone the annual benefits ranged between five and twelve times the annual costs. This represented a small part of the story because the most important benefit was reducing human death and suffering.

This draft is preliminary. Please do not quote without permission. Comments most welcome.

Alan L. Olmstead ([alolmstead@ucdavis.edu](mailto:alolmstead@ucdavis.edu)) is Professor of Economics and Director of the Institute of Governmental Affairs at the University of California, Davis, 95616 and Paul W. Rhode ([prhode@email.unc.edu](mailto:prhode@email.unc.edu)) is Professor of Economics at the University of North Carolina, Chapel Hill 27599-3305 and a Research Associate at the NBER.

## **An Impossible Undertaking: The Eradication of Bovine Tuberculosis in the United States<sup>1</sup>**

At the dawn of the twentieth century tuberculosis (TB) was the leading killer of humans in the United States, accounting for roughly 148 thousand deaths in 1900. At that time tuberculosis caused about one out of every nine deaths.<sup>2</sup> Death represented only a fraction of the disease's cost because countless others were permanently crippled or lingered in pain as they wasted away. The toll of the disease was staggering. Irving Fisher, eminent economist and health advocate, estimated the total losses to the US from the tuberculosis in 1906 "exceeds \$1,100,000,000 per annum. Should this annual cost continue indefinitely, it means a total capitalized loss of \$22,000,000,000."<sup>3</sup> Converted into current (2001) purchasing power using the consumer price index, this would represent over \$430 billion.

Although the exact number is not known, it is probable that at least 10 percent of these TB sufferers had contracted the bovine form of the disease, mostly likely from cattle, cattle products, or swine infected by cattle. Beginning in the late nineteenth century, a series of discoveries by the leading proponents of the "Germ Theory of Disease," greatly advanced the

---

<sup>1</sup> We would like to thank seminar participants at the University of Virginia, Virginia Tech, the Triangle Economic History workshop, and the Agricultural History Center University of California, Davis Workshop on Agricultural Productivity Change over the Centuries, December 2002. We would also like to thank Julian Alston, Wayne M. Dankner, Susanne Iranzo, Don Klingborg, Peter H. Lindert, Shelagh Mackay, Dolores Rhode, Edward Rhode, Calvin Schwabe, Joseph D. Schwarz, and James Steele for comments and assistance.

<sup>2</sup> US Bureau of the Census, "Tuberculosis in the United States" in *Mortality Statistics 1907*, (Washington DC: GPO, 1909), Table 17, p. 516; US Bureau of the Census, *Mortality Rates 1910-1920* (Washington DC: GPO, 1922), pp. 16, 27.

<sup>3</sup> Irving Fisher, "The Cost of Tuberculosis in the United States and its Reduction," *Transactions of the Sixth International Congress on Tuberculosis* Vo. III *Proceedings of Section V, Hygienic, Social, Industrial, and Economic Aspects of Tuberculosis* (Philadelphia: William F. Fell, 1908), p. 34. By both his and our reckoning, Fisher's estimates represent an honest attempt at a lower-bound assessment of the cost of tuberculosis. At every important juncture in his analysis, he accepts data and makes assumptions that understate the cost of the disease. Most notably his procedure gives zero value to the pain and suffering of the victims and of their friends and families. To put Fisher's estimate of the present discounted cost of the disease into perspective, twenty-two billion dollars was roughly equal to the entire net national product of the United States in 1906.

Fisher calculated that the cost per tuberculosis death was roughly \$8,000 in 1908 dollars. This figure is remarkably close to the \$8,430 lower-bound estimate of the value of life (actually \$30,305 in 1967 purchasing power) reported by Seung-Wook Kim and Price V. Fishback, "Institutional Change, Compensating Differentials, and Accident Risk in American Railroading, 1892-1945," *Journal of Economic History* 53: 4 (Dec. 1993), p. 811(entire article is pp. 796-823) based on the OLS regression coefficients estimating the compensating wage differentials for accident risk for railroad workers over the 1893-1909 period.

scientific understanding of tuberculosis (see the timeline presented in Table 1). The single most important step was Robert Koch's discovery of the tubercle bacillus in 1882. By the end of first decade of the twentieth century there was a consensus that the bovine form of tuberculosis was distinct from the human form, and mounting evidence that the bovine form could be passed between animals and humans, and that in humans the bovine type could produce symptoms that were clinically indistinguishable from the human strain.<sup>4</sup> This evidence, while still considered controversial by many prominent scientists, led to a comprehensive and wholly unprecedented campaign to eradicate bovine tuberculosis in the United States. At the outset in 1917 one of America's leading agricultural spokesmen, Henry C. Wallace, questioned whether the proposed campaign was not "an impossible undertaking."<sup>5</sup>

The eradication campaign was a massive endeavor that touched farms in virtually every county as the federal government in cooperation with state and local governments systematically tested and retested cattle, destroying those that reacted positively. Between 1917 and 1940 veterinarians administered roughly 232 million tuberculin tests and ordered the destruction of about 3.8 million cattle (from a population that averaged 66.4 million animals over this period). A high percentage of those condemned were valuable dairy cows or breeding stock. In addition, the federal, state, and local governments strengthened their meat inspection programs, instituted prohibitions to control the shipment of diseased animals, improved tracking systems in order to identify farms that had shipped tuberculous animals, and required that all cattle imported into the United States be quarantined and tested for TB. Closely coupled with these measures was another initially controversial campaign to pasteurize the urban milk supply. Commercially pasteurized milk, which was virtually non-existent in 1900, composed about 98 percent of the milk supply in major cities in 1936.<sup>6</sup>

---

<sup>4</sup> Some basic terminology needs clarification. The formal name of the bovine strain of tuberculosis is *Mycobacterium bovis*, which is often summarized as *M. bovis*. The corresponding terminology for the human strain of tuberculosis is *Mycobacterium tuberculosis* and *M. tuberculosis*. The bovine strain can be passed from cattle to humans and vice versa (as well as to a number of other animals). There are other strains of tuberculosis, but they do not figure prominently in our analysis. A second terminology note: A contagious disease is generally defined as one that spreads from organism to organism whereas an infectious illness spreads and grows within an organism's body.

<sup>5</sup> Howard R. Smith, head of the private body leading the anti-TB campaign, noted that in 1917 Henry Wallace responded to his request for support: "Smith, don't you think this is an impossible undertaking?" Howard R. Smith, *The Conquest of Bovine Tuberculosis in the United States*, (Somerset, MI: By Author, 1958), p. 12. This book has no printed page numbers; we begin our pagination at the start of Smith's text.

<sup>6</sup> A. W. Fuchs and L. C. Frank, *Milk Supplies and Their Control in American Urban Communities of Over 1,000 Population in 1936* Public Health Bulletin No. 245 (Washington, DC: GPO, 1939), p. 29. In a work-in-progress, we are investigating the spread of milk pasteurization, which went hand-in-hand with tuberculin-testing.

The early cooperative state-federal testing program was voluntary, but it eventually evolved into a compulsory system that forced the laggards to join up. Until the development of the tuberculin test in the early 1890s, veterinarians could only identify about one in ten infected live animals and even post-mortem visual inspections in slaughterhouses failed to reveal about one-half of tuberculous carcasses. The disease's deceiving appearances created confusion and contributed to farmer resistance in some areas. Some of the world's most prominent TB researchers argued that the destruction of prized purebreds or even of whole herds was often arbitrary and inefficient, and many farmers complained that the program's administration was heavy handed. In fact, we know of few instances where the police power of the United States government was so ruthlessly exercised in peacetime. However, despite all the complaints and repeated attempts to dope the tests, the overwhelming majority of farmers freely participated.

The program was an enormous success. By 1941 every county in the United States, was officially accredited free of bovine tuberculosis (that is with an infection rate below 0.5 percent). Although the costs of the eradication program had been huge, the savings to farmers and meat packers alone resulting from increases in animal productivity and a decline in number of condemned carcasses at slaughterhouses exceeded the costs by at least a ratio of ten to one. However the real savings were not to be found in the farm sector. The spillover effect on human health was the main story. In 1940, before effective chemotherapy was available, new cases of bovine type TB in humans raised in the US had become a rarity. By our reckoning (see Appendix 1), the eradication program, coupled with the spread of milk pasteurization, was saving at least 20 to 25 thousand lives a year in the United States in 1940 from TB (many times this number of infants were saved annually via the effect of pasteurization on reducing the incidence of intestinal disorders). Although unprecedented, the US program did create a model for others to follow. Advanced countries had access to the same information available in the United States, but with the exception of Canada almost all failed to bite the bullet, preferring less draconian, but largely ineffectual measures.<sup>7</sup> Bovine TB remained endemic, with cattle infections rates in some European countries as high as 80 percent. It was not until after World War Two that most European nations finally copied the American model and imposed compulsory TB test-and-slaughter programs along with the mandatory pasteurization of urban

---

<sup>7</sup> Among European nations, Finland appears to have been most aggressive in addressing the problem prior to WW II. J. Arthur Myers and James H. Steele, *Bovine Tuberculosis Control in Man and Animals* (St. Louis, MO, W.H. Green, 1969), pp. 256-60.

milk supplies. The cost of their delay was hundreds of thousands of totally avoidable cases of human tuberculosis.

### **The Incidence and Impact of Bovine TB on Cattle**

Bovine tuberculosis was an insidious disease because apparently healthy animals could be both infected and contagious. Indeed “[m]ost *M. bovis* infected cattle appear normal.”<sup>8</sup> After the disease progressed for several years, infected cattle exhibited symptoms similar to those exhibited by humans suffering from TB. The cattle developed tuberculous lesions in organs, tissues, and bones. Infected animals had difficulty gaining or maintaining weight, cows experienced a roughly 10-25 percent reduction in milk production and problems in breeding, and draft cattle lost strength and endurance.<sup>9</sup> Eventually cattle might show external signs of lesions, have coughing attacks (if the disease settled in the lungs), become lethargic and die prematurely. The disease spread among cattle through contaminated feed, milk, straw, water, and even air. Contaminated sputum and feces were frequently the culprits. The disease spread between herds through the introduction of diseased animals as replacements, additions, or breeding stock. It was also transmitted by incidental contact with infected animals--across neighbor's fences, from shared water supplies, at livestock shows or county fairs--or with contaminated materials. A cattle owner could avoid the disease by maintaining a physically isolated, closed herd but this entailed significant costs by reducing the scope for specialization, limiting ability to replace animals, and by increasing inbreeding.

The inability to detect the disease in its early (but contagious) stages made its control nary impossible before the modern era. In 1890, Robert Koch developed tuberculin, a sterilized, filtered concentrate of the broth in which the tubercle bacilli was cultured. Koch initially believed tuberculin, which did not include the bacilli, could be used to vaccinate humans. This

---

<sup>8</sup> Committee on Bovine Tuberculosis, Board of Agriculture, National Research Council, *Livestock Disease Eradication: Evaluation of the Cooperative State-Federal Bovine Tuberculosis Eradication Program* (Washington DC: National Academy Press, 1994), p. 13

<sup>9</sup>The estimate of a 10 percent reduction in milk productivity appears both in early sources such as A. D. Melvin “The Economic Importance of Tuberculosis of Food-producing Animals” in *Twenty-Fifth Annual Report of US Bureau of Animal Industry for 1908* (Washington DC: GPO, 1910), p. 103 and in the recent literature including National Research Council, *Livestock Disease Eradication*, p. 56. Steele suggests a 25 percent reduction.

E. T. Faulder, *Bovine Tuberculosis: Its History, Control and Eradication* New York State Department of Agriculture and Markets Bulletin 218 (Albany, NY: Sept. 1928), p.14 states “the producing life of a dairy animal infected with tuberculosis is often cut in half.”

hope proved wrong, but in 1890 and 1891 a number of researchers demonstrated the agent did produce a reaction in animals previously exposed to the disease, allowing the detection of TB in animals without visible symptoms.<sup>10</sup> Early applications of the tuberculin test showed that the extent of the infection was far more widespread than had been suspected based on visual post-mortem inspections at slaughterhouses. The tests demonstrated that even the most prized and apparently healthy animals could harbor the disease. For example, it was a revelation when 35 out of the 40 dairy cows tested on Queen Victoria's Windsor estate reacted positively.<sup>11</sup> In 1892, Leonard Pearson, who had studied under Koch, introduced tuberculin testing in Pennsylvania and soon veterinarians in several states were experimenting with the process.

The earliest form of the tuberculin test involved injecting the substance beneath the animal's skin (the subcutaneous test) and checking for signs of a fever. This was a very costly procedure in terms of the veterinarian's time and the relatively large quantity of expensive tuberculin administered. To obtain an accurate result the veterinarian had to take the animal's temperature, typically three to four times at two hour intervals, prior to the injection to establish a baseline reading. Beginning about 6 hours after the injection the veterinarian again took temperature readings every two to three hours, continuing the process for up to 24 hours after the injection was given. Surviving test charts show that to test a herd of about a dozen animals, the veterinarian had to be on site for about 36 hours inspecting each animal from 10 to 15 times. A far simpler and cheaper approach, suited to mass testing, became the standard practice in 1920: the tester injected a few drops of tuberculin into the skin (the intradermic test) of subject animal—usually in a flap in the tail—and then returned to visually re-examine the animal two to three days later. This procedure represented an important technological advance that allowed one tester to do the work of five or six using the older method. According to William W. Wright of the Illinois Division of Animal Industry, "It is a big weeks work, under the present system, for one man to make more than three tests a week and oftentimes only two tests are made. With the

---

<sup>10</sup> Bernhard Bang of Denmark or W. Gutmann (aka Guttman) of Russia usually receive the credit for this breakthrough, but it appears that many researchers hit on the same principle at about the same time. J. Arthur Myers, *Man's Greatest Victory Over Tuberculosis* (Springfield, IL: Charles C. Thomas, 1940), p. 115; US Bureau of Animal Industry, *Special Report on Diseases of Cattle, 1916* (Washington, DC: GPO, 1916), pp. 416-17.

<sup>11</sup> Thomas Dormandy, *The White Death: A History of Tuberculosis*, (London: Hambleton, 1999), pp. 330-31; René Dubos and Jean Dubos, *The White Plague: Tuberculosis, Man, and Society*, (Boston: Little-Brown, 1952), p. 260. Both Dormandy and the Dubos assert the testing of the royal cows occurred in 1890. This would have been very early given that many accounts date first use of tuberculin as a diagnostic aid in 1891. Myers, *Man's Greatest Victory*, pp. 114-15.

intradermal method a man could...go over two or three herds and possibly more in one day.”<sup>12</sup> If the site of the intradermic injection showed significant signs of swelling, the animal was labeled a reactor. Under either procedure, detecting a “reaction” was clearly a judgment call, as enraged cattle owners would at times protest. Both false positives and false negative occurred, with some of the false negatives due to recent previous exposure to tuberculin that “produces a tolerance...lasting for about six weeks.”<sup>13</sup> Thus the standard testing protocol required the subject animal had not been tested in the previous 60 days.

Rates of TB infection tended to be higher among closely confined cattle such as dairy cows and purebred stock than in free range animals raised in the open air. The prevalence of the disease also increased with the animal’s age.<sup>14</sup> Older stock obviously had a longer period of exposure to contract the bacteria and more time to develop full-blown, highly contagious cases. As a result of these forces, bovine TB was more common in the proximity of major cities, in dairy herds, and, more generally, in the “advanced” agricultural regions of the country. Early tuberculin-test results often shocked public health officials when a majority of the animals in many herds tested positively. When Massachusetts began a state testing program in the mid-1890s an astonishing 50 percent of the over 24,000 cattle tested reacted positively. In the New York City vicinity, 75 percent of the cattle initially tested in Orange County reacted.<sup>15</sup> It is likely that sample bias and overly generous compensation schemes overstated the problem in many of these early programs, but early efforts to test every cow in selected cities uncovered startling high infection rates.

Contemporaries noted the irony that attempts to improve the local livestock by importing purebred cattle were often responsible for increasing the incidence of the disease. The relative

---

<sup>12</sup> William W. Wright to J. R. Mohler (Chief of the BAI), January 20, 1920, RG 17, Records of the BAI, Central Correspondence, 1913-1953, Entry 3, Box 337, National Archives.

<sup>13</sup> *Diseases of Cattle, 1916*, pp. 417-18; Smith, *Conquest*, pp. 7-9, Ulysses Grant Houck, *The Bureau of Animal Industry of the United States Department of Agriculture: Its Establishment, Achievements and Current Activities* (Washington, DC: By Author, 1924), pp. 364-66; Myers, *Man’s Greatest Victory*, p. 125. The USDA also experimented with a third testing method using eye drops that produced a milky discharge in infected stock.

Note that proportion of false positives (or more precisely the probability that a positive test has identified an uninfected animal) depends on the prevalence of the disease. As the disease becomes less common, a positive result under a given test procedure is more likely to be false. National Research Council, *Livestock Disease Eradication*, pp. 17-19. According to this source, the probability that an uninfected animal would test positive was less than two percent.

<sup>14</sup> US Bureau of Animal Industry, *Diseases of Cattle 1916*, p. 409 observed that taking the number of cases involving animals 1 year and under as one unit, animals from ages 1 to 3 accounted for 10 times the number of cases, those 3 to 6 from 30 times the number and those age 6 and over 40 times. (Note these are not probabilities)

<sup>15</sup> Myers, *Man’s Greatest Victory*, pp. 272-74; Smith, *Conquest*, p. 46

backwardness of the cattle industry in the Southern states helps explain that region's relatively low bovine tuberculosis rates. In part due to the prevalence of Texas tick fever, which made dairying less profitable and often killed purebreds imported into the region, Southern herds were relatively isolated from external sources of contamination.

Based on a sampling of tuberculin tests and slaughterhouse inspections, the prevailing wisdom circa 1915 was that 10 percent of the nation's dairy cattle and 1 to 2 percent of its beef cattle were infected with bovine TB.<sup>16</sup> The aggregate rate was approximately 5 percent in 1915, up from 3.5 percent eight years earlier. A growing health concern over this period was tuberculous meat, which accounted for about two-thirds of beef carcasses condemned during the early decades of the federal meat inspection program.<sup>17</sup> Nevertheless, the US cattle infection rate was significantly below the levels prevailing in European herds, where 25 to 80 percent of the cattle were tuberculous. Prior to the widespread use of tuberculin testing, slaughterhouse records indicated the seriousness of the problem in Europe and offered an indication of how the incidence of the disease might have increased in the US if left unchecked. Around the turn of the twentieth century 14.6 percent of the carcasses in Prussia and 29.3 percent in Saxony were tuberculous. In Leipzig 36.4 percent of the cattle slaughtered had tuberculosis lesions. As in the United States, German slaughterhouse records vastly understated the problem because where the tuberculin test was administered, detected infection rates skyrocketed, with up to 80 percent of the animals reacting.<sup>18</sup> Almost one-half of the cattle tested in neighboring Belgium and Denmark in the 1890s reacted positively.<sup>19</sup> The situation in most of Europe remained critical; in the early 1930s testing indicated that from 60 to 86 percent of the cattle in northern Germany and about 40 percent of the cows in England were infected.<sup>20</sup>

---

<sup>16</sup>Edward B. Mitchell, "Animal Diseases and Our Food Supply," in *USDA 1915 Yearbook* (Washington, DC: GPO, 1916), p. 168; *Diseases of Cattle, 1916* p. 409. Given that (1) the share of younger animals in the flow of cattle into slaughterhouses was larger their share in the cattle stock and (2) younger animals were less likely to be infected with TB, the infection rate crudely measured at the slaughterhouse will be lower than the average in the overall population.

<sup>17</sup>In addition, according to US Bureau of Animal Industry, *Annual Report 1922*, (Washington, DC: GPO, 1922), p. 142 "probably 90 of the all tuberculosis in swine is from cattle sources." This fraction declined as bovine TB was brought under control.

<sup>18</sup>US Bureau of Animal Industry, *Special Report on Diseases of Cattle, 1912* (Washington, DC: GPO, 1912), p. 417; Orland, "Cow's Milk and Human Disease," p. 11; Myers, *Man's Greatest Victory*, p. 222.

<sup>19</sup>US Bureau of Animal Industry, *Diseases in Cattle, 1912* p. 417.

<sup>20</sup>Myers, *Man's Greatest Victory*, p. 222 Infection rates probably increased in most continental European countries during World War Two. But infection rates went down in Denmark because the Danes systematically shipped reactors to Germany.

Before the start of the US eradication program, the national infection rate was rising at an alarming pace, and without intervention it likely would have approached the European rates at least for dairy cows. The proportion of slaughtered cattle retained (that is showing visual signs of TB lesions) by federal meat inspectors rose from one percent in 1908 to about 2.5 percent by 1917. Of the roughly 220,000 carcasses retained about 46,000 were so infected that they were sent to the rendering tanks and used for fertilizer and about 3,000 were boiled to be used in sausage or pet food. The remainder were trimmed of the obvious lesions and declared fit for human consumption.<sup>21</sup>

### **The Impact of Bovine Tuberculosis on Humans**

Although there was a growing consensus of the incidence of bovine TB infections in cattle by the first decade of the twentieth century, the incidence and impact of the disease on humans was still hotly debated. Researchers had long speculated that humans contracted tuberculosis from cattle, but the quest to understand the linkage was a slow process with many blind alleys and heresies. In 1898 Theobald Smith showed that there were small but identifiable differences in strains obtained from bovine and human sources.<sup>22</sup> Ironically, Smith's breakthrough contributed to one of the most serious setbacks in the anti-bovine tuberculosis movement. In 1901 Robert Koch, who was the undisputed luminary of the TB research community, misinterpreted the significance of Smith's findings, and proclaimed that dairy products contaminated with virulent bovine tuberculosis posed little threat to humans. He compounded the damage by arguing that there was no need to take any measures against infected animals.<sup>23</sup> Koch continued to downplay the risks to humans from bovine tuberculosis in the face of growing evidence to the contrary. To add to this mistake many physicians, swayed by Koch's

---

<sup>21</sup> Melvin, "Economic Importance," pp. 101-02. Given the number of cattle slaughtered in 1960, and assuming the rate of condemnation remained constant, implies that by that date about 92,000 carcasses would have been sent to the rendering tanks or sterilized; in fact only 282 carcasses met this end. But without the eradication program the infection and condemnation rates would have soared, and it is reasonable to assume that there would have been a minimum of several hundred thousand condemnations by 1960. This estimate assumes that the USDA did not tighten its inspection standards. As a crude indication of how fast the disease could spread, bovine tuberculosis probably did not enter Sweden and Finland until the 1840s and by the end of the nineteenth century it is likely that 25 percent of the cattle were infected. Myers and Steele, *Bovine Tuberculosis Control* pp. 256-57, 280-81.

<sup>22</sup> Myers, *Man's Greatest Victory*, pp. 106-09. Among other evidence Ravenel reported on cases where veterinarians had accidentally inoculated (cut) themselves while working with tuberculin animals and shortly thereafter the wounds developed tuberculin lesions. Myers, *Man's Greatest Victory*, pp. 211-15.

<sup>23</sup> Myers and Steele, *Bovine Tuberculosis Control*, p. 57.

pontifications, believed that the exposure to bovine TB was a blessing for children because it was less virulent and provided immunity against the more dangerous human form.

Prominent researchers in America and Europe hotly contested Koch's views. In 1902 M. P. Ravenel isolated the bovine microorganism from a child with tuberculous meningitis. In 1905 Theobald Smith developed a simpler method to culture the two types of tuberculosis and succeeded in isolating the bovine type from the mesenteric lymph nodes of a child. In principle Smith's discoveries made it possible to determine the extent of bovine infection in humans, but in practice his method was still an expensive and delicate process that that would not gain widespread clinical application.<sup>24</sup> Nevertheless, evidence began to mount that a serious problem existed. As examples, in 1910 a review of the bacteriological analysis for over 1500 cases in New York indicated that bovine bacillus was responsible for 66 percent of the non-pulmonary tuberculosis in children, and a 1914 study of 72 children suffering from tuberculosis of the cervical lymph nodes found that 65 had the bovine type. Similar early warnings were coming out of Europe. Following Koch's remarks in 1901 the English and German governments established blue ribbon commissions to investigate the possible transmission of bovine tuberculosis to humans. Both commissions concluded (in 1907 and 1911 respectively) that the bovine type of tuberculosis represented a serious threat to humans.<sup>25</sup>

Over the long process of learning about bovine tuberculosis, there remained considerable controversy about how serious that threat was before animal control measures and milk pasteurization were underway. Scattered studies conducted in the United States and Europe before pasteurization became widespread suggest that from roughly 1 to 13 percent of pulmonary infections and 20 to 60 percent of the non-pulmonary cases (infecting the skin, genitourinary system, bones, joints, intestines, eyes, lymph nodes, brain, and other organs) were of the bovine type.<sup>26</sup> As an indication of the lack of precision in estimating the overall incidence of the bovine strain, the Centers for Disease Control's summary evaluation is that between 1900 and 1930, "M. bovis was isolated from 6%-30% of human tuberculosis patients in the United States and the

---

<sup>24</sup> It was not until 1938 that a "quicker" method of differentiating between the bovine and human types was developed. Even this simpler method required about seven weeks. Myers, *Man's Greatest Victory*, p. 226.

<sup>25</sup> Myers, *Man's Greatest Victory*, pp. 200, 218-219; Dankner et al., pp. 20-24.

<sup>26</sup> J. Arthur Myers, *Tuberculosis: A Half Century of Study and Conquest* (St. Louis, MO: Warren H. Green, 1970), p. 235; Grange and Collins, p. 227; Ravennel, 1901, pp. 234-35; William Clunie Harvey and Harry Hill, *Milk: Production and Control* (London: H. K. Lewis, 1936), p. 26; Chester Linwood Roadhouse and James Lloyd Henderson, *The Milk Market*, 2<sup>nd</sup> ed. (New York: McGraw-Hill, 1950), pp. 65-66; Myers, *Man's Greatest Victory*, pp. 219-29.

United Kingdom.”<sup>27</sup> Holman and Duff’s 1939 summary of studies from around the world suggested that the total incidence of bovine tubercle bacilli in human tuberculosis infection was approximately 10 percent.<sup>28</sup> They estimated that the rate for the United States was 11.7 percent, but many of the investigations underlying this result dealt with the period after milk pasteurization had become widespread. Thomas Dormandy, after a thorough review of the literature, speculated that bovine tuberculosis accounted for about 15 percent of all TB deaths around 1900 (presumably in Western Europe and the United States).<sup>29</sup> The current medical literature commonly puts the bovine share in the 20-30 percent range before 1917.<sup>30</sup> Everyone

---

<sup>27</sup> CDC, *Mortality and Morbidity Weekly Report*, 39:12 (30 March 1990), pp. 201-213; A. E. Wight, Elmer Lash, H. M. O’Rear, and A. B. Crawford, “Tuberculosis and Its Eradication,” in USDA, *Keeping Animals Health:1942 Yearbook of Agriculture* (Washington DC: GPO, 1942), pp. 237-249, especially, p.242.

<sup>28</sup> W. L. Holman and Lyman Duff, “The Bovine Tubercle Bacillus in Human Tuberculosis,” *American Journal of the Medical Sciences*, Vol. 192, Series 2, (1936), p. 413; entire article is pp. 411-27.

<sup>29</sup> Dormandy, *White Death*, p. 329.

<sup>30</sup> For example, Lewis S. Forbes, “The Programme for the Eradication of Tuberculosis in the United States of America and Some Possible Applications in Africa,” *Bulletin of Epizootic Diseases of Africa* 12 (1964): 429-35 noted on p. 431 that “In the early days, 20% of cases were due to the bovine bacillus, but from 1947-57, there were only 12 episodes involving human with identified bovine TB...” in the US. D. G. Pritchard, “A Century of Bovine Tuberculosis 1888-1988: Conquest and Controversy,” *Journal of Comparative Pathology* 99 (1988), pp. 357-99 on p. 371 asserts that “following the recognition that 25 per cent of human deaths from tuberculosis were due to *M. bovis*, an eradication programme began in 1917” in the US. Herbert M. Sommers, “Disease Due to Mycobacteria Other Than *Mycobacterium tuberculosis*,” pp. 386-403 in Guy P. Youmans, ed., *Tuberculosis* (Philadelphia: W. B. Saunders, 1979) on p. 388 states “In 1917 it was estimated ... that approximately 25 percent of the deaths from tuberculosis in adult human beings was caused by *M. bovis*” in the US. Dankner et al.’s recent analysis of case studies dealing with the interwar years in England note that “bovine tuberculosis accounted for up to 25% of all human tuberculosis and 2 to 5% of pulmonary tuberculosis,” and that the situation changed little during the Second World War (pp. 21-22). Calvin Schwabe, who is one of the world’s leading veterinary epidemiologists and historians of zoonosis (diseases communicable from animals to humans), offers even higher estimates of the the incidence of bovine type infections in humans. Schwabe asserts that in the United States around 1900 “the form of the disease that then accounted for up to 10 percent of human pulmonary tuberculosis, and almost all human tuberculosis of other organs, was contracted from cattle rather than from other people.” Given that non-pulmonary cases accounted for at least 20 percent of all cases, Schwabe’s claim suggests the bovine strain accounted for up to roughly 30 percent of all human TB infections. Elsewhere, Schwabe noted that “before an eradication attempt began in Denmark and Germany, bovine-type infection accounted for 20 to 40 per cent of human pulmonary infections and 60 per cent of non-pulmonary infections in those two countries.” Calvin W. Schwabe, *Cattle, Priests, and Progress in Medicine* (Minneapolis, MN: University of Minnesota Press, 1978) p. 190, and Calvin W. Schwabe, *Veterinary Medicine and Human Health*, 2<sup>nd</sup> ed. (Baltimore: Williams & Wilkins, 1969), p. 48. Unfortunately the recent medical literature does not reconciled the claim that bovine type infections accounted for roughly 20 percent human infections with the lower rates of about 10 percent found in tests conducted early in the twentieth century. According to Dankner, a review of the testing procedures employed in the early case studies gives no reason to suspect large undercounts, but there could have been significant sample biases if the test populations had underrepresented rural residents who had had frequent contact with cattle. In fact, some support for the high end estimates is found in case studies showing very high infection rates among populations known to have consumed the milk of tuberculin cows and by Swedish cross-sectional studies showing a high correlation of human and animal infection. Also in rough agreement with the high-end estimates, is Franklin Top’s claim that the bovine type accounted for at least 30 percent of human tuberculosis in southern Germany in the late 1940s and early 1950s. Top served in Germany during the Allied occupation and was a noted authority on preventive medicine.

agrees that the bovine infections, and in particular non-pulmonary manifestations, were far more common in children, especially infants, due to the consumption of untreated milk and less resistance to the disease.

### “TB or not TB”

One can usefully think about the spread of a contagious disease such as TB in the standard logistic framework. At a given time, a fraction,  $F(t)$ , of the animal population is infected; another fraction,  $S-F(t)$ , is susceptible to the disease but as yet uninfected; and the remainder,  $R=1-S$ , is resistant to the disease. In the standard logistic model, the disease spreads as the infected population comes into contact (randomly) with the susceptible but uninfected population. The extent of new infections,  $f(t)$ --that is, the change in  $F(t)$ -- can be expressed as:

$$(1) \quad f(t)=d(F(t))(1-F(t)/S)$$

where  $d$ , the diffusion rate, reflects the contact rate between the animals and the contagiousness of the disease on contact. Note that chances a susceptible but uninfected animal will become infected rise as the proportion infected increases.<sup>31</sup> By the standard logistic formula, the proportion of the animals infected at time  $t$  will be:

$$(2) \quad F(t)=F(0)S/(F(0)+(S-F(0))\exp(-dt))$$

where  $F(0)$  is the initial extent of infection.

---

Both recent and historical studies suggest that roughly 50 percent of adult bovine TB sufferers exhibit extra pulmonary infections (meaning that 50 percent also had pulmonary symptoms) whereas about 10 to 15 percent of *M. tuberculosis* cases show extra pulmonary manifestations. In young children about 90 percent of bovine infections are extra pulmonary. Tanya Roberts, “A Retrospective Assessment of Human Health Protection Benefits from the Removal of Tuberculosis Beef,” *Journal of Food Protection*, 49: 4, (April 1986) pp.294-95, Ingela Sjogren and Ian Sutherland, “Studies of Tuberculosis in Man in Relation to Infection in Cattle,” *Tubercle*, Vol. 56, (1974) pp. 113-27. Wayne M. Dankner, Norman J. Waecker, Mitchell A. Essey, et al., “*Mycobacterium bovis* Infections in San Diego: A Clinicoepidemiologic Study of 73 Patients and a Historical Review of a Forgotten Pathogen,” *Medicine*, 72: 1, (1993), pp. 11-37. Interview with Dankner, 9 August 2002. Steele in Myers and Steele, *Bovine Tuberculosis Control*, p. 264 and interview with Steele, 1 August 2002.

<sup>31</sup> This setup ignores the mortality effects on the disease, which in an extreme case, may wipe out the entire susceptible population.

Suppose the uninfected cattle produce a value of  $V_U$  per period whereas the infected cattle produce  $V_I < V_U$ . In period  $t$ , the value of output will be  $V_U - F(t)(V_U - V_I)$ . Given a constant interest rate,  $r$ , the present value at time 0,  $PV(0)$  of the total herd subject to a disease spreading according to (2) is:

$$PV(0) = V_U/r - (V_U - V_I)F(0)S \int_0^{\infty} [\exp(-rt)/(F(0) + (S - F(0))\exp(-dt))] \partial t$$

Control measures, by altering  $S$ ,  $d$ , and  $F(0)$ , influenced the extent and spread of the disease in several ways.<sup>32</sup> Using vaccines could reduce  $S$ , the susceptible fraction of the population by increasing the fraction that is resistant—unfortunately, the bacillus Calmette-Guèrin (BCG) vaccine developed for bovine TB proved ineffectual.<sup>33</sup> It also proved difficult to identify resistant breeds of livestock to replace the susceptible animals.<sup>34</sup>

Enacting quarantines and segregating infected animals served to reduce  $d$ , the diffusion rate. This approach was made more difficult for TB cattle because before the advent of tuberculin testing, it was hard to identify contagious stock through visible inspection. One unintended consequence of the partial application of control measures was that farmers in areas where quarantines and testing was in force faced incentives to export their infected or untested animals to areas without effective quarantines. Thus, enacting measures to reduce local contact and infection rate could lead the disease to spread to other areas, which here appears as an increase in  $d$ .

A final set of control measures involved eradicating the infected population—intervening directly to reduce  $F(0)$ . This was at the heart of the test-and-slaughter program enacted in the USDA. The obvious difficulty in this approach was the loss suffering to farmers from the destruction of his infected stock. If the test yielded no false negatives, this approach could eliminate the disease from the population. Even if the eradication campaign was not absolutely effective, it could reduce the fraction infected,  $F(0)$ , to such low levels that the rate of new

---

<sup>32</sup> In addition to controlling the disease, one could also work to raise the value of the infected animals towards that of the uninfected stock. Pasteurization of the milk supply works towards this end.

<sup>33</sup> The BCG vaccine used a live attenuated strain of *M. bovis* to promote immunity. The approach worked for some populations of humans, but not all. It also causes positive reactions to the tuberculin skin tests. The vaccine did “not provide a useful or cost-effective level of protection in cattle.” National Research Council, *Livestock Disease Eradication*, p. 32.

<sup>34</sup> National Research Council, *Livestock Disease Eradication*, p. 16 noted there is considerable genetic variability, even with a single herd, in the susceptibility of the cattle to the disease. D. E. Salmon, *Tuberculosis of the Food-Producing Animals*, Bureau of Animal Industry Bulletin No. 38 (Washington, DC: GPO, 1906), p. 15 observed that the disease would “spread through the cows of a herd until 50 to 80 per cent of the animals were affected.”

infection remained low. The disease could be held in check as long as the death rate from eradication equaled the rate of new infection.<sup>35</sup>

One can show analytically that  $\partial PV(0)/\partial F(0) < 0$  and  $\partial^2 PV(0)/\partial^2 F(0) > 0$ . That is, the present value of the herd decreases as the initial level of infection rises, but does so at a decreasing rate. This implies that the marginal benefit of reducing  $F(0)$  through the test-and-slaughter program is positive and rising as the level of infection falls.<sup>36</sup> Hence, there are increasing returns to the eradication efforts, lending credence to the old adage that an ounce of prevention was worth a pound of cure.

This result highlights the differences between the US and Europe. In the early twentieth century, the extent of infection in the US was sufficiently low (roughly 5 percent) that TB could be reduced to background levels (below 0.5 percent) at relatively low cost. In Europe, achieving such low levels would have involved the slaughter of a far larger fraction of their livestock, resulting in a period of shortages. Reducing the fraction infected by 4.5 percentage points, as in the US, would have had relatively little impact in Europe on either the extent of infection or the rate of new infections.<sup>37</sup>

To make this point concrete, consider a hypothetical example where the real interest rate,  $r$ , is 3 percent per annum; the value of uninfected animals,  $V_U$ , is 100; the value of infected animals,  $V_I$ , is 75; the share susceptible,  $S$ , is 80 percent; and the diffusion rate,  $d$ , is 5 percent per annum.<sup>38</sup> Reducing the initial share of the population infected,  $F(0)$ , from 5 to 0.5 percent points raises the present value by over five times more than the same 4.5 percentage points

---

<sup>35</sup> The logistic model above does not fully capture the spatial aspects of the contagious process. Given that contact was more likely to occur between cattle locally, it was more beneficial to concentrate resources to eliminate the disease from a single area than to get the job half done in two areas.

<sup>36</sup> The rising marginal benefits (to an eradication program as the prevalence of the disease falls) also imply it is optimal to push for total eradication unless the marginal cost of reducing  $F(0)$  rises even faster. One can also show  $\partial PV(0)/\partial d < 0$ , hence it is advantageous to slow the spread of the disease (e.g. via quarantines). But note  $\partial^2 PV(0)/\partial F(0)\partial d$  and  $\partial^2 PV(0)/\partial^2 d$  are more difficult to sign analytically. This means that it is less clear how the marginal benefits change with the changing intensity of quarantine.

<sup>37</sup> Offsetting this is the likelihood that the cost of finding a given fraction of infected animals depended on the extent of the disease. The fact that the tests were imperfect and that the proportion of false-positives in total test results rose as the prevalence of the disease declined, suggest the marginal costs were likely increasing. But undoubtedly it remained more expensive to control the disease where it was more fully established.

<sup>38</sup> The diffusion rate of 5 percent is roughly consistent with the fraction infected increasing from 3.5 to 5 percent over a decade as occurred in the United States before the testing program started. The ratio of  $V_I$  to  $V_U$  is in line with the statement of Walter Willcox that “an animal suffering with the disease loses at least one-fourth of its value.” Walter F. Willcox, “The Economic Loss to New York State in 1907 from Tuberculosis” *Transactions of the Sixth International Congress on Tuberculosis* Vo. III *Proceedings of Section V, Hygienic, Social, Industrial, and Economic Aspects of Tuberculosis* (Philadelphia: William F. Fell, 1908), pp. 41-42; entire article is pp. 37-45.

change reducing  $F(0)$  from 40 percent to 35.5 percent. The non-linear nature of contagion processes means the same control effort has a greater effect if the infection rate is low (i.e. the disease is caught early).

### **The Eradication Program in Practice**

The US Bureau of Animal Industry's bovine TB eradication program was a largely new effort. There were no ready models for the US campaign. Although Bernhard Bang of Denmark and other leading veterinarians had long discussed the desirability of eradicating tuberculous animals, almost all European states had opted for less aggressive control programs emphasizing segregation of infected animals and attempts to exclude from the food supply the meat and milk from animals with the full-blown disease. Most Europeans argued that the disease was so prevalent that eradicating all infected animals would cause unacceptable food shortages—better impure food than insufficient food. Even Bang admitted in 1896: “In most European states a compulsory and quick butchering of all these animals is out of the question, the number of the reacting animals is so very large.”<sup>39</sup>

Bang accepted a less radical approach involving eliminating the sick animals, periodically testing the entire herd and segregating the reactors from the non-reactors (and raising the calves of the reactors with the non-reactors.) He also advocated thoroughly disinfecting the stalls. Germany followed an even less aggressive approach developed by Robert Von Ostertag that did not employ the tuberculin test at all. Only animals with open lesions were destroyed and visibly infected animals were tracked. The Manchester plan, prevalent in England, called for periodic testing of milk for tubercle bacilli; when discovered, authorities traced the milk tracing back to the dairy and tested the individual animals.<sup>40</sup> Europeans also put more faith in the use of the BCG vaccine (see note 33).

The USDA did have established programs to combat hog cholera, pleuropneumonia, foot-and-mouth disease, and Texas tick fever. But given the differing biological natures of these threats, none provided a ready off-the-shelf model for the anti-TB campaign. Unlike pleuropneumonia, foot-and-mouth disease, or Texas tick fever, bovine tuberculosis was already

---

<sup>39</sup> Cited in Myers, *Man's Greatest Victory*, pp. 245-46.

<sup>40</sup> Myers, *Man's Greatest Victory*, p. 265.

well established throughout America's cattle herds. A national effort would be required. Unlike hog cholera or Texas tick fever, there was neither an effective vaccine nor a cure for TB. Eliminating the disease requiring eliminating the diseased animals. The disease, however, was not so contagious that control required the total depopulation and disposal of the carcasses of both infected and exposed animals as with foot-and-mouth disease.<sup>41</sup> Instead, except in highly advanced cases of TB, after the lesions were removed, the affected animal's flesh would enter the meat supply. As it evolved, the BAI's test-and-slaughter anti-TB eradication campaign became the model for other disease eradication programs in the US, for example the anti-brucellosis effort, as well as many anti-bovine TB campaigns around the world.

In designing the eradication program, it was necessary to carefully consider the nature of the disease as well as the incentives individual farmers faced. It was desirable to provide incentives to reveal the presence of the disease (by testing) and to encourage the destruction of the diseased animals. Indemnity and salvage schemes could help accomplish these goals. But the payments could not be so generous that they discourage farmers from taking private measures to prevent infection or certainly not so high as to encourage infection or reporting false positive results.<sup>42</sup> It was also desirable to reduce the spread of the disease both within a given farm and then across farms and farming regions. To limit the spread on a given farm dictated

---

<sup>41</sup> According to modern cost-benefit studies in the US and Canada, an aggressive depopulation program to remove all animals in a herd exposed to TB (and thus avoiding the potential introduction of the "hidden disease" from animals with false negative reactions) did have advantages over the traditional test-and-slaughter approach. But this conclusion probably at least in part reflects the low prevalence of the disease in the modern period. National Research Council, *Livestock Disease Eradication*, pp. 53-62.

<sup>42</sup> Livestock sanitary officials generally supported paying indemnities, but only with limits. At its 1921 Annual Meeting, the Board of US Sanitary Live Stock Commission resolved "no practice should be followed which places any premium on diseased animals." *25<sup>th</sup> Annual Meeting of US Sanitary Live Stock Commissioners, 1921*, p. 106. The example of Massachusetts in the mid-1890s re-enforced the opposition to overly generous indemnities. The state gave full compensation for animals reacting positively to tuberculin tests, including those tested privately. Many farmers slaughtered and received indemnity money for a large fraction of their herds, leading to the suspicion that they were buying up sickly animals and reported them as reactors.

J. L. Hills and F. A. Rich, *Bovine Tuberculosis*, Vermont Agricultural Experiment Station Bulletin No. 42 (July 1894), pp. 65-66 presented a detailed and sophisticated discussion of the pros and cons of indemnity system. Among its list of advantages were that it (a) encouraged disclosure and more complete eradication whereas paying no indemnity encouraged concealment and dispersal; (b) recognized property rights; and (c) shared the program's cost with public, which was gaining health benefits.

Its disadvantages were that it (a) encouraged disease; (b) encouraged the importation of diseased animals from areas where prices were lower than the indemnities; (c) created a burden on the taxpayers; and (d) insured breeders and owners against their own mistakes and misfortunes. The policy debates often raised the issue of whether the indemnities were justified. Opponents argued given that the farmers raising damaged crops did not warrant compensation; those raising diseased animals did not either. Even among the advocates of indemnities, many including H. R. Smith of the Chicago meat-packers were often in principle opposed to government handouts but believed the partial indemnities lubricated the wheels to increase the program's effectiveness.

testing entire herds (rather than only suspect animals), removing the reactors, and disinfecting the premises thoroughly before returning the non-reactors. For these reasons, authorities often conditioned the indemnity payments on the testing the entire herd and on evidence of good faith efforts to disinfect the premises. To reduce the spread across farms within a region, the authorities could increase the geographic scale of the test-and-slaughter campaign to cover townships, counties, and even larger units under the so-called area plan. Quarantines on reactors and untested animals were employed to limit the spread of the disease across regions.<sup>43</sup>

Achieving a Coasian solution (by assigning property rights) appears problematic due to the difficulties in observing and documenting the spread of the microorganism.<sup>44</sup> Another crucial difficulty to solving the problem privately arose from the nature of the test. The use of tuberculin often created immunity in the subject animal to further reactions for a period of six weeks or more. Thus, under privately administered tests, it was possible for a livestock owner to detect the disease and then sell reactors to unknowing buyers who could not check themselves in due time. The practice of selling at auction and shipping out suspect animals was common even before the advent of tuberculin testing and was considered a major force leading to the long-distance spread of the disease in the US. “Plugging the test,” by prior exposure of the animal to

---

<sup>43</sup> After the progress of the eradication campaign created a large “TB-free” region, the threat of quarantining livestock products from untested areas (as well as potential competition of products bearing “TB-free” labels, induced laggard states such as California to accelerate their efforts. M. E. McDonald, “Tuberculosis Control in California,” in *Proceeding of 65<sup>th</sup> Convention of California Fruit Growers and Farmers, Dec 7-9, 1932* (Sacramento, 1932), p. 22.

<sup>44</sup> According a standard textbook treatment, the Coase theorem requires 1. “the cost of bargaining do not deter the parties from finding their way to the efficient solution” and 2. “resource owners can identify the source of damages to their property and legally prevent the damages.” Harvey S. Rosen, *Public Finance* Fifth Ed. (New York: Irwin-McGraw-Hill, 1999), p. 100. As suggested in literature on preventing accidents, the efficient solution implied investing in preventive measures up to the point maximizing the difference between the expected costs of the disease and the costs of its prevention. But given that the potential beneficiaries from voluntary prevention measures were numerous, free-rider problems induced high bargaining costs in attaining the efficient solution. This undermined the first requirement of the Coase Theorem. Furthermore, given the microscopic nature of the disease vector, the manifold channels of infection, and the disease’s long gestation period, the costs involved in identifying the source of the infection of a particular animal or person to the satisfaction of any court were, in most cases, prohibitive. This undermined the second requirement of the Coase Theorem. A further complication in cases of contagious diseases, unlike the standard pollution examples, the owner of the infected and contagious animal could always evade responsibility by claiming his property was damaged through an earlier infection from another owner’s infected and contagious animal.

It is important to recall that from the late nineteenth century on, almost every state did have clearly defined property rights concerning animals infected with dangerous contagious diseases: their ownership was illegal and, if discovered, diseased animals were subjected to immediate destruction with compensation issues to be settled later.

tuberculin, represented such a problem that the test material became a controlled substance in most jurisdictions by the 1910s.<sup>45</sup>

Of course, it is not sufficient to consider the operation of individual incentives alone. As repeated experimental evidence reveals, many people are willing to contribute more to public good provision—here, suffer a loss of their own diseased cattle to reduce the aggregate level of infection—than pure self-interest would dictate. And again, for many people, “equitable” treatment matters—they are unwilling to participate in a mutually beneficial venture if they receive a small share of the benefits relative to the costs they bear. Cooperation with the program presumably would have been low if the losses from condemnation threatened to push resource-poor farmers out of business. Apart from any sense of “fairness,” farmers were more likely to be willing to participate if they knew their neighbors were also cooperating—otherwise participating farmers stood a high risk of talking a loss, only to see their herds re-infected. As the USDA literature frequently noted, successful eradication efforts required “the assistance and hearty cooperation of the owners.”<sup>46</sup>

### **State and Local Control Efforts**

Despite the common perception of the late nineteenth century as a period of *laissez faire*, virtually every American state government had in its law books regulations concerning infectious and contagious animals. This represents an example of what Jonathan R.T. Hughes called the “Governmental Habit.”<sup>47</sup> As the mysteries of TB were uncovered, the regulatory drive at the state level focused on slowing the spread of this deadly disease. The state and local programs displayed enormous variety in keeping with the 1932 observation of Supreme Court Justice Louis Brandeis that under the US federalism, the states were the “laboratories of reform.”<sup>48</sup> But in the judgment of the US BAI historian the “[m]any spasmodic attempts” by state and local

---

<sup>45</sup> Smith, *Conquest*, pp. 18-20 notes cases of Illinois farmers and livestock dealers who were caught cheating.

<sup>46</sup> J. A. Kiernan and L. B. Ernst, “The Toll of Tuberculosis in Live Stock” in USDA, *1919 Yearbook*, p. 282. In addition to destroying the reacting cattle, preventing further infection required cleaning up contaminated manure and straw from the barn and farmyards. These costs fell entirely on the farmers.

<sup>47</sup> Jonathan R.T. Hughes, *The Governmental Habit Redux: Economic Controls from Colonial Times to the Present*, 2nd ed. (Princeton, NJ: Princeton University Press, 1991).

<sup>48</sup> In a classic 1932 dissenting opinion, Supreme Court Justice Louis Brandeis observes, “It is one of the happy incidents of the federal system that a single courageous state may, if its citizens choose, serve as a laboratory; and try novel social and economic experiments without risk to the rest of the country.”

governments - to control bovine TB before 1917 failed to yield permanent results because “these attempts lacked uniformity and force.”<sup>49</sup> In particular state-level programs were relatively inefficient in controlling the inter-state shipment of TB-infected animals that contributed to the spread of the disease. As a result, even when a state paid farmers to slaughter reactors, the herds were often re-infected by new untested stock.

The most vigorous early campaign began in Massachusetts. In 1894, the state enacted a strict, compulsory anti-TB program with quarantines and comprehensive testing. In 1896 and 1897 the state spent \$550,000, largely to compensate owners for the full value of their infected animals (up to a limit of \$60 per head). Before opponents succeeded in gutting the plan, over 11,000 reactors were identified and slaughtered. Because of opposition from cattle and dairy interests, the state continued on a voluntary basis emphasizing visual inspections as opposed to tuberculin testing. In 1908 the state inspected over 38,000 herds with over 230,000 animals. Use of the more accurate tuberculin test was restricted to cattle shipped into the state and to those farmers who requested it.<sup>50</sup>

Pennsylvania adopted less aggressive plan, advocated by the State Livestock Sanitary Board, in 1896. Visibly ill animals were destroyed with the owner keeping the salvage value and receiving a partial indemnity (limited to \$25 for grades and \$50 for purebreds). The state also provided free voluntary tuberculin testing. Owners of reactors could choose either slaughter with partial compensation or keeping the reactors in isolated herds and selling their milk only if heated to 185 degrees F for 10 minutes. The latter choice essentially mirrored Bang’s approach. Given the complications of keeping segregated herds and low price received for sterilized milk, most Pennsylvania cattle owners opted for the slaughter with indemnity approach.<sup>51</sup>

Testing began at the Wisconsin Experiment Station dairy in 1893 where over 80 percent of the 30 purebreds reacted. When post-mortem inspections confirmed the presence of lesions, cattle breeders swamped the experiment station to have their private herds tested. The campaign received a boost when W. D. Hoard, the editor of the influential *Dairyman*, endorsed the testing program. If an animal reacted the owner could quarantine it or sell it to a federally inspected

---

<sup>49</sup> U. G. Houck, *Bureau of Animal Industry*, pp. 350-51.

<sup>50</sup> Myers, *Man’s Greatest Victory* p. 272-74, 283; Michael E. Teller, *The Tuberculosis Movement: A Public Health Campaign in the Progressive Era* (New York: Greenwood Press, 1988), p. 20; M. H. Reynolds, “The Problem of Bovine Tuberculosis Control,” *American Veterinary Review* (January 1909), pp. 454-56—the whole article page spread is 449-481. Teller suggested a roughly 50 percent reaction rate in Massachusetts was “inflated by farmers who took an opportunity to get rid of sick or unproductive cows at public expense.” Teller, p. 19.

<sup>51</sup> Reynolds, “The Problem,” pp. 457-58.

stockyard for immediate slaughter. In either case the state offered no compensation. If the farmer rejected these options, the state would dispose of the animal, keeping the salvage value, and pay the farmer a partial indemnity. By focusing on dairy cows and breeding stock the state achieved pockets of success, significantly reducing the number of sick animals that were most likely to infect humans or spread the disease to other cattle.<sup>52</sup>

By 1900, many other states, especially in Northeast and Midwest, also had programs. Illinois provided voluntary testing of herds but no compensation for reactors. In New Jersey, the State Tuberculosis Commission offered testing of individual animals (rather than herds) and paid full compensation for reactors slaughtered. The State Board of Health bore the responsibility for TB control in New York, condemning reactors with partial compensation. In Michigan, reactors were either slaughtered without state compensation or kept isolated. Delaware, Maine, Maryland, Minnesota, New Hampshire, Rhode Island, and Vermont also enacted legislation falling within this range of policy options.<sup>53</sup>

In addition, as part of the pure milk movement, most major cities and eventually hundreds of smaller towns issued regulations requiring tuberculin-testing of the cows supplying urban markets. Many were paper measures because few cities allocated sufficient resources to enforce the new rules vigorously. These municipal regulations faced numerous legal challenges. But the higher courts, beginning with the Minnesota Supreme Court in 1896 and including the U.S. Supreme Court in 1913, almost universally upheld the constitutionality of these public health measures.<sup>54</sup>

In 1900, 17 states required tuberculin testing of cattle imported from other states for breeding and dairy purposes. The number increased to 34 states one decade later and by 1917, such restrictions were virtually universal.<sup>55</sup> In addition, the USDA required tuberculin testing for animals imported into the US in 1900. Requirements for testing all animals entering state and

---

<sup>52</sup> Eric E. Lampard, *The Rise of the Dairy Industry in Wisconsin* (Madison, WI: State Historical Society of Wisconsin, 1963), pp. 188-89; *Biennial Report of the Wisconsin State Department of Agriculture for the Years 1915-1916*, Bulletin No. 10, Madison, 31 December 1916, pp. 83-95 and *Biennial Report for the Years 1919-1920*, pp. 41-47; Reynolds, "The Problem," pp. 451-54.

<sup>53</sup> Myers, *Man's Greatest Victory*, pp. 278-79; D. E. Salmon, *Legislation with Reference to Bovine Tuberculosis*, US Bureau of Animal Industry Bulletin No. 28 (Washington DC: GPO, 1901).

<sup>54</sup> James A. Tobey, *Legal Aspects of Milk Sanitation*, 2nd ed. (Washington, DC: Milk Industry Foundation, 1947), p. 76. The US Supreme Court cases was *Adams v. Milwaukee* (1913) 228 U.S. 572, 57 L. Ed 971, 33 S. Ct. 610.

<sup>55</sup> Myers, *Man's Greatest Victory*, p. 267; R. W. Hickman, "The Eradication of Cattle Tuberculosis in the District of Columbia, in USDA, *1910 Yearbook* (Washington, DC: GPO, 1911), p. 231; entire spread is pp. 231-42.

county fairs followed in 1908.<sup>56</sup> The animals testing positive in most state programs were to be permanently marked—state laws variously specified branding, tattooing, or tagging the animal’s cheeks or ears. However these regulations could be easily evaded. C. U. Duckworth, chief of the California Division of Animal Industry, reported that cattle without left ears became so common in that state that when he arrived there Duckworth thought he had “run into a new breed of cow.”<sup>57</sup> Relying on authorities in the sending state to conduct thorough tests created obvious incentive problems. An offsetting potential problem was that states might treat the requirements with excess seriousness as a means of erecting artificial barriers to interstate trade.

Even after the passage of state laws, bootlegging apparently remained common. W. J. Butler showed that of the 1,646 purebred cattle imported into Montana with official tuberculin test charts, 145 reacted in a 60-90 day retest. There is considerable evidence that farmers in fact succeeded in “plugging the test.” This led many states to amend existing quarantine laws by requiring the that payment to shippers of breeding animals transported from other states be withheld until the cattle passed a test administered 60 days after the date of shipment. In addition, the BAI controlled access to tuberculin in order to prevent its fraudulent use. These steps are credited with significantly reducing the “beggar-thy-neighbor” practice of unloading breeding infected stock.<sup>58</sup>

For all their problems in handling interstate externalities, the early state and municipal programs did provide rigorous proving ground to sort out what worked, especially regarding local eradication efforts. Many features of the post-1917 cooperative state-federal program, most specifically the partial compensation scheme, evolved directly out of the experiences with the state programs. The state-level experiments were valuable because as J. A. Kiernan, head of the federal TB eradication bureau, observed the program designers could not simply “figure this out on paper.”<sup>59</sup> These state initiatives also helped solidify interested groups of farmers, livestock packers, and health/sanitary officials to lobby for a national solution.

---

<sup>56</sup> National Research Council, *Livestock Disease Eradication*, p. 35.

<sup>57</sup>C. U. Duckworth, “Tuberculosis Eradication in the State of California,” *Forty-Second Annual Meeting of the United States Live Stock Sanitary Association* (1938), p. 227, entire article is p. 227-31.

<sup>58</sup> Myers, *Man’s Greatest Victory*, p. 268; Smith, *Conquest*, pp. 10-11. The problem of farmers plugging the test evidently plagued the testing program in Great Britain where tuberculin remained easily accessible. Dormandy, *White Death*, pp. 336-37.

<sup>59</sup> US House of Representatives, Committee on Agriculture, *Tuberculosis in Livestock, Hearings on H.R. 6188, a bill making appropriation for the control and eradication of tuberculosis in live stock*, 65th Congress, 2nd session, 1918, p. 10.

## Cooperative State-Federal Program

In 1906, the federal government began its active involvement in TB eradication as part of its campaign to improve the quality of the milk supply of Washington, DC. US Bureau of Animal Industry officials provided voluntary tuberculin testing to all area cattle growers who requested the service. The initial results were disturbing—18 percent of the tested animals reacted. In late 1909, the Commissioners of the District of Columbia made TB testing mandatory for all of the roughly two thousand cattle in the District and for any animals intended to be shipped in. (Thus, the program extended beyond the boundaries of the District, with tests conducted on about 6,000 cattle in Maryland and Virginia each year.) The Commissioners also established a relatively generous compensation scheme to reimburse owners of slaughtered reactors. These efforts yielded quick results, including a double-digit percentage point decline in the fraction of tested animals reacting between 1910 and 1911. In 1919, only 0.63 percent of the cattle in the District reacted to the test. The BAI officials, who were using Washington, D.C. much as their laboratory and demonstration farm for TB eradication efforts, proudly trumpeted their success. This experience convinced BAI officials that bovine TB could be eradicated nationwide.<sup>60</sup>

The beginning of the cooperative state-federal program was modest. On 4 March 1917, Congress appropriated \$75,000 for bovine TB eradication. The funding included no provision for indemnities. The 1917 Act did not specifically require the slaughter of reactors. However the power to condemn and order the destruction of animals capable of spreading disease across state boundaries had been granted the US Secretary of Agriculture in 1884. This federal power had been used against animals with plueropneumonia and foot-and-mouth disease but not against tuberculous cattle (except in the Washington DC area) until this time. The new legislation did lead to the establishment on 1 May 1917 of the TB Eradication Division within the US Bureau of Animal Industry.

In December 1917, the US Bureau of Animal Industry approved a national plan advanced by the US Live Stock Sanitary Association and various purebred cattle-breeder associations to provide voluntary testing for cattle herds. The initial focus was on purebred animals, “the

---

<sup>60</sup> Hickman, “Eradication,” pp. 231-42.

foundation of our breeding stock.” The authorities assembled lists of targeted purebred herds to be tested, culled of reactors, and then retested. Those herds that passed were certified as “Tuberculosis-Free Accredited Herds;” which allowed owners to ship their animals across state boundaries without further testing for one year. An indemnity scheme, with relatively limited federal matching funds, was also enacted.<sup>61</sup> The initial focus on purebred herds (which typically included a mix of grade and purebred stock) helps explain the extraordinary high proportion—over one-third—of reactors that were purebreds in the early years of the program. This share was roughly ten times the proportion of purebreds in the national cattle population.<sup>62</sup> The 1917 regulations also made provision for the declaration of tuberculosis-free areas when all of the herds in a given area met the requirements to become “tuberculosis free accredited herds” and for “modified accredited” areas which met the less restrictive requirement that reactors made up less than 0.5 percent of cattle population.

In October 1918, President Wilson signed legislation, promoted by meatpackers and veterinarians, increasing anti-TB appropriations to \$500,000 and including a Senate provision authorizing the first federal indemnities.<sup>63</sup> Beginning in fiscal year 1919, the federal government was committed to match state indemnities, up to one-third of the difference between the animal’s appraised value and salvage value. The federal payments were initially capped at \$50 per head for registered purebreds and \$25 per head for grade cattle.<sup>64</sup> Legislation passed in 1919 tripled federal funding to \$1.5 million with separate appropriations of \$1 million for indemnities and the remainder for operating expenses.

States began authorizing increased appropriations, with New York and Illinois leading the way. Most of the states in the North Central region soon followed. The voluntary program

---

<sup>61</sup> J. A. Keirman, “The Accredited-Herd Plan in Tuberculosis Eradication,” in USDA, 1918 *Yearbook*, pp. 215-20.

<sup>62</sup> According to US Bureau of the Census, *Fourteenth Census of United States, 1920* Vol. V, *Agriculture* (Washington, DC: GPO, 1922), p. 634, some 3 percent of US beef cattle and 2.9 percent of dairy cattle were registered purebred stock. The overall share had increased slightly by 1930, when 3.36 percent of US cattle were purebreds. US Bureau of the Census, *Fifteenth Census of United States, 1930* Vol. IV, *Agriculture: General Report, Statistics by Subjects* (Washington, DC: GPO, 1932), p. 581. By the late 1930s, only 4-6 percent of the reactors were purebreds, a fraction closer to but still above the purebred share in the total population.

<sup>63</sup> Myers, *Man’s Greatest Victory*, p. 295.

<sup>64</sup> To provide an example, assume that a purebred cow was appraised at \$200 and had a salvage value of \$50. In this case the federal government would match a state’s payment up to the \$50 limit. The state could pay more than \$50. These limits changed gradually as livestock prices increased and declined. The federal limits were raised to \$70 for purebreds and \$35 for grade animals in 1929 and then returned to their former levels in 1932. The limits for grade animals was reduced to \$20 in 1935 and then raised back to \$25 the next year.

with indemnities proved highly popular.<sup>65</sup> By 1922, all but 6 states were participating. Over 16 thousand herds with 364 thousand animals had achieved “accredited herd status” and 162 thousand herds with 1.5 million animals has passed one test. As of August 1922, almost 65 thousand farmers 0.5 million cattle were on the waiting list for testing.<sup>66</sup> In this period, the program was directed primarily at “cleaning up” the breeding stock, essentially the capital good producing sector, to provide healthy animals to serve as replacements when the eradication campaign became more general.<sup>67</sup>

State spending increased from about \$2 million in 1918 to \$13 million by 1927. It is important to realize that there were intense debates in literally every state legislature in the country (and in many county assemblies) over the precise details of the state programs and that except during a brief period in the mid-1930s the states and counties largely carried the ball. In the late 1920s and early 1930s, the state and local governments were spending more than twice the federal appropriation of about \$6 million. By the mid-1930s, the state expenditures decreased and emergency federal funds came online, leading the contribution ratio to reverse. At the peak in FY 1935, the federal government spent about \$18 million whereas states contributed \$9 million to the program. When the program entered the maintenance phase in the 1940s

---

<sup>65</sup> One measure of the program’s relative popularity was that the alternative approaches, common in Europe, never gained wide favor in the US. For example, the US Bureau of Animal Industry, *1923 Annual Report*, pp. 237-38 examined the use of segregated herds where tubercular animals of high breeding value were retained rather than slaughtered. The calves were separated from their dams and fed milk only after pasteurization. After locating only 201 segregated herds containing less than 2500 animals, the Bureau concluded, “the more direct and effective methods of eradication are regarded as more practicable and find greater favor in this country.” As we detail below, the one exception was in California

<sup>66</sup>C. W. Larson et al., “The Dairy Industry,” in USDA, *1922 Yearbook*, p. 341. Entire article is pp. 281-390.

<sup>67</sup> In light of studies investigating the socio-economic characteristics of early adopters of new technologies, it is informative to compare the early successful participants in the eradication program with the general population of cattle owners. In the first few years of the eradication campaign, the USDA published a series of lists of the thousands of cattle owners (detailing their names, location, animal breeds, and herd size) whose herds achieved the status of either “accredited” or “once tested without reactors.” The primary intention was to indicate where purchasers of replacement cattle or other cattle products could find supplies free from contamination by bovine tuberculosis. We can use the 1919 list to construct summary statistics (based on the population totals and, where necessary, from a one-in-six sample) to compare the early participants with the aggregate characteristics of the cattle sector as reported in the 1920 *Census of Agriculture*. These results, in line with expectations, indicate that the program animals were disproportionately dairy animals—79.0 percent in the program versus 29.5 percent in the total population—and of purebred stocks—29.5 versus 3.0 percent. The average sizes of herds in the program were also larger --15.9 head per herd for all cattle and 18.1 for dairy cattle-- than the 1920 US averages--12.4 and 4.4, respectively. (In each case, the difference was statistically significant at any conventional level.) Finally, relative to total cattle population in 1920, the program animals were over-represented in New England, the South Atlantic, and East South Central states whereas they were significantly under-represented in West South Central and Pacific states.

(involving total spending of about \$5-6 million per year) the ratio returned to roughly two state dollars for every one federal dollar.

In spring of 1922, the US BAI and state livestock sanitary officials began to shift the emphasis of their “clean up” efforts from individual herds to entire areas (such as counties). Under the area plan all of the cattle in the area were tested during a relatively short period of time. The BAI officials argued the systematic eradication of the disease in an entire area was advantageous because it reduced the chance of re-infection of the tested animals from neighboring herds and was “much more economical than the promiscuous testing of herds under the accredited plan.”<sup>68</sup> Typically, the area campaigns were associated with a vigorous local publicity effort. Initiation of the program in many states required the securing the signatures on petitions of at least a majority of the cattle owners in the area.<sup>69</sup> A county (or even a sub-county unit) could achieved the “modified area” status after testing revealed less than one-half of one percent of the local cattle were tuberculous.<sup>70</sup>

The federal legislation left the states considerable flexibility in participating in the eradication effort and establishing their own indemnity programs. Most states adopted schedules paralleling the federal plan, with similar payment shares and limits.<sup>71</sup> In some eastern states where livestock prices were higher the state indemnity limits were higher. States also differed over whether and how much county governments contributed to the payments. Among the more interesting modifications, adopted by Montana, was to reimburse the farmer for the full appraised value if the condemned animal was found free of TB lesions in a post-mortem examination. This essentially insured the farmers against false positive test results, which was a source of considerable complaints against the eradication program. But, circa 1928, the most common way to deviate from the standard program was to have no state program at all;

---

<sup>68</sup> US House of Representatives, *Agricultural Appropriation Bill, 1925*, 68<sup>th</sup> Cong., 1<sup>st</sup> Sess. House Report No. 223 (Washington, DC: GPO, 1924), p. 136; and *Agricultural Appropriation Bill for 1927* (Washington, DC: GPO, 1924), p. 147.

<sup>69</sup> Smith, *Conquest*, p. 28. Some states such as New York and California required the signatures of at least 90 percent of cattle owners in an area to initiate the program.

<sup>70</sup> J. A. Kiernan, “Bovine Tuberculosis Being Suppressed” in USDA, *1926 Yearbook*, p. 182; entire article is pp. 180-83. Cattle from “modified areas” could be moved interstate without tuberculin testing for a period of three years. After three years, the “modified area” status would be renewed if tuberculin testing of a least 20 percent of the area’s cattle indicated the infection rate remained below 0.5 percent. This procedure meant that under the completed program in steady state, about 7 percent of the nation’s cattle would be tested every year. Note that in herds or areas with reactors, the animals required retested after the reactors were removed.

<sup>71</sup> US House of Representatives, *Agriculture Department Appropriation Bill, 1930* 76<sup>th</sup> Cong, 2<sup>d</sup> Sess., 1930, House Report 1956, pp. 107-08; *1928 Congressional Record*, pp. 5, 505.

Alabama, Arkansas, and California did not provide any state indemnities and, therefore, received no federal matching funding.

The level of state effort, as reflected in the reduction of farmer's losses through indemnities, did have a measurable impact on the early progress of the eradication effort. One way to examine this issue is to explore the state-level relationship between the percentage of farmer's losses (as a share of appraised value) with the fraction of testing and eradication completed before 1930 (in the total performed by 1949). Table 2 reports the results of ordinary-least-squares regressions explaining state-level variation in the percent of reactors found and testing in the early phase of the program. (The dependent variables also include the total share of animals tested by 1949 that reacted, the price per head of cattle in 1920, and the 1920 share of dairy stock in the total value of cattle.<sup>72</sup>) The results indicate strong, statistically significant, negative effects of farmer's loss on both the share of reactors found and tests completed. The clear interpretation is the incentives mattered, that is, in states where indemnities were greater in either 1919 or 1928, the program made more rapid progress by 1930. There were also strong, statistically significant, negative effects of the infection rate, as measure by the total share of reactors, on both the share of reactors found and tests completed. Thus, where the problem was more serious less progress was made in the early years. Note that progress is measured here in relative, rather than absolute terms; the states with higher infection rates may have actually slaughtered more animals. These results are consistent with the theoretical model analyzed above. The percent of dairy animals in the value of all cattle has a positive, significant effect on the percent of reactors discovered early, but little effect of the percent of testing. The value per head of cattle is not statistically significant in any regression.<sup>73</sup>

---

<sup>72</sup> The share reacting serves a proxy for the proportion of animals infected with TB, but it is not perfect. Given the same initial rate of infection, a state with a swifter effective eradication campaign will have a lower cumulative share reacting because the disease will have less chance to spread. Also note that the share of the cumulative number of reactors found by FY1930 of the total found by FY1949 is uniformly greater than the share of cumulative tests conducted by FY1930 of the total conducted by FY1949, which makes sense because testing continued even after most reactors were destroyed.

<sup>73</sup> One caveat considering these results is that even within a given payment structure, local authorities could alter the program's cost to the farmer through decisions regarding the appraised value, the assessment of whether the animal was purebred or grade, and through efforts to improve the salvage market. The dollar value caps on federal indemnities limited but did not completely remove the ability of local authorities to game the system to benefit their neighbors. The salvage value generally depended on the market value of the animal's beef and hide. State authorities and meat packers often claimed to be working hard to keep salvage values up. Myers, p. 318 noted Institute of American Meat Packers urge the payment of equal prices for reactors and untested animals of the same quality. Everett C. Brown, "Salvage of Reactors from the Standpoint of the Packers and the Owners, 27<sup>th</sup> Annual Meeting US Live Stock Sanitary Commissioners, 1923, pp. 130-31. The appraisal value went beyond the beef value

Some sense of the overall generosity of the program is provided in Figure 1. It charts the changing values of the average payments received, the average appraised values, and the average salvage values over the 1919-49 period. It also compared these values with the average US price for all cattle and for dairy cattle. Over the 1919-49 period, the correlation coefficient of the average value per head with the average appraisal value was 0.946 and with the average salvage value was 0.987. This strongly suggests that state officials were setting the key program values with a keen eye to changing market conditions. Both the appraised value and total payments remained above the average value of cattle per head and even above the average value of dairy cattle. (The appraisals and payments are below the average value of purebred cattle, for the period when data are available.) The average salvage value was generally only slightly below the average value of all cattle. These findings would appear to imply the program was quite generous to owners of reactors, but this conclusion is probably mistaken. Aggregate US data do not reflect the differences in geographical distribution of the reactors, which tended to be located in the East where livestock values were higher.

The payment structure of the program took a crucial turn under the Jones-Connally Cattle Act of 1934, more specifically under an amendment by Senator Robert La Follette. This legislation provided emergency federal money to continue the undertaking and dropped the requirement that states provide matching funds. This dramatic change occurred when depression-era fiscal constraints let states to cut back. The emergency funds made it “possible to extent the work to sections of the country where no local funds are available.”<sup>74</sup> In addition (and perhaps to prevent the laggards from reaping all of the rewards), the Act also initiated a state-

---

to encompass the animal’s dairy and breeding value. Under standard practice, a team including one state and federal official, “considering the market value of the animal and by keeping within the maximums allowed,” determined the appraisal value. US House, *Agricultural Appropriation Bill, 1927*, 69<sup>th</sup> Cong., 1<sup>st</sup> Sess. (Washington, DC: GPO, 1926), p. 168. Mohler noted, “in case of disagreement ... (the two men) together appoint a third man.”

How well did the appraisal and salvage values reflect the reactor’s true market value? We know that in almost every state, average appraisal values were well in excess of the average value of cattle—the typical 1929 ratio of appraisal value to average prices was 1.76. This is not entirely surprising given that cattle with valuable attributes – dairy stock, older animals, and purebreds—were more likely to be tuberculous. The reported average salvage value equaled 58 percent of the price of all cattle and 42 percent of the average value of dairy cattle. (These figures are based on unweighed state averages.)

<sup>74</sup> US House of Representatives, *Agricultural Department Appropriation Bill for 1939* (Washington, DC: GPO, 1938) pp. 242-45. The main purpose of the La Follette Amendment was to authorize the purchase under the AAA of livestock in drought-stricken areas during the one of the most severe periods of the Dust Bowl. The Jones-Connally Act, more generally, made cattle a “basic commodity” as part of the AAA.

federal brucellosis test-and-slaughter campaign modeled largely on the anti-TB effort.<sup>75</sup> Unprecedented sums of federal money (\$25-30 million per year) flowed into these campaigns.

Figure 2 charts the number and percent of all cattle tuberculin-tested annually between 1917 and 1953. The series indicate the program's rapid growth during the late 1910s and throughout the 1920s. Between fiscal years 1919 and 1929, the number of tests increased at a rate of over 35 percent per year. The advance of the program appears to have lost steam over the 1930-33 period as legal challenges to the program arose in Iowa and California and, more generally, the agricultural economy fell into crisis. Jones-Connally Emergency Legislation of 1934 revitalized the effort. At the campaign's peak in 1935-36, the BAI hired over 900 veterinarians and 500 helpers as temporary employees to test nearly 25 million cattle per year, or roughly one-third of the nation's 68 million cattle. After this "big push," tuberculin testing slowed to the 8-12 million levels, or about one-tenth of the nation's bovines. After 1941, almost all testing was for "maintenance" purposes.

The Figure also illustrated the breakdown between the accredited herd and area plans (in the figure the difference between the total number of cattle tested and the number tested in the accredited herd plan represents the number tested in the area plan). In its first year of operation (FY 1922) the area plan was about four-tenths of the size of the accredited herd plan. By FY1923, the area plan tested more cattle than the herd plan and it continued to grow much faster. By the mid-1930s, it was ten times larger.

Another way to measure the spread of the eradication effort is to examine the number of US counties engaged in the program and those certified as modified accredited areas (see Figure 3). The first counties received the accredited status in 1923. By 1 July 1927, 347 counties (of 11 percent of the approximately 3070 counties in the continental US) qualified. By 1933, the share exceeded fifty percent. The Jones-Connally program was associated with a major jump in participation and by the end of 1940 all counties qualified. In the context of the broader literature on institutional and technological diffusion, the spread of the BTB eradication program was relatively rapid because it only required one decade for the fraction of accredited counties to rise from less than ten percent to over ninety percent of all counties.

---

<sup>75</sup> Brucellosis (aka Bang's disease and contagious abortion) caused abortions in livestock and undulant fever in humans. The disease did differ in nature from TB.

At the start of the federal-state campaign in 1917, BAI estimated that about one in 20 cattle in the United States were tuberculous.<sup>76</sup> Beginning in 1922, the Bureau of Animal Industry took biennial (and after 1934 annual) surveys of the extent of bovine TB infection in the United States. Figure 4, graphing the estimated infection rate of all cattle and the reaction rate for tested animals, provides a sense of the rate of progress achieved nationally. (The survey estimates and reaction rates differ due to sample selection in the population subject to the test.) In 1922, about four percent of all US cattle were infected with the disease. Within six years, the infection rate had been cut in half. The sharpest proportional rate of reduction occurred during the 1934-37 period, under the Jones-Connolly emergency program. By the end of the 1930s, the national rate had fallen below 0.5 percent, the upper bound for the counties included as “modified accredited areas.”

The year 1940 marked the close of the eradication program in an important sense that was hidden in the aggregate data. Progress in reducing the disease among cattle geographically was highly uneven, due to differing rates of initial infection, levels of contact, and widely varying effort levels to eradicate the disease. The series of shaded Bureau of Animal Industry county-level maps, displayed in Figure 5, provide a more informative view of the program’s progress. The first (available) map reveals the distribution of the disease as on 1924. Portions of the Northeast and the Midwest suffered levels of infection exceeding 15 percent of their cattle. The Southeast was relatively free from the disease. In July 1923, 17 counties spread across Indiana, Michigan, North Carolina, and Tennessee were in the first cohort of “modified accredited areas.” The 1930 map shows the lightly infected regions of the country had spread and especially rapid progress occurred in the Midwestern region.<sup>77</sup> By way of contrast, herds in California and New York remained heavily infected. In fact, the infection rates increased in California between 1924 and 1930. Problems remained in these states as of 1937, at which time most of the remainder of the country was virtually free from the disease. When California’s Merced and Kings counties, were finally certified in 1940, bovine tuberculosis had been brought under control across the continental US.

---

<sup>76</sup> A. E. Wight et al., “Tuberculosis and Its Eradication,” p. 237.

<sup>77</sup> As Smith (*Conquest*, p. 29) notes, the program’s progress nationally created market pressures for its adoption throughout the Midwest. After a large fraction of their stock proved to be reactors, eastern dairymen began to demand replacements from the more western states. Given eastern regulations aimed at preventing re-introduction of the disease, the purchases were concentrated in clean areas, leading to premiums of dairy cows from accredited counties.

The pattern of the progress against bovine tuberculosis is highly exceptional in the US economic and agricultural history, representing an intriguing case where those who were last were often first, and those who were first, last. By almost every measure from literacy, to living standards, to rates of adoption of new technologies, California and New York were always among the most progressive regions of the country and North Carolina, with its impoverished tobacco road farmers, among the most backward during the first half of the twentieth century. But these states achieved control of bovine tuberculosis in an order opposite from what would normally be expected. As we shall see below, this reversal cannot be explained solely by the initial infection rates, because the laggard status of California appears initially the result of institutional and legal forces, (that is, questions regarding the constitutionality of paying indemnities) and later, at least according to many accounts, due to the ethnic unity and strident and well-organized opposition of the segments of the state's dairy farmers. At a deeper level, the regional differences across the US appear less significant. There was only a twelve-year gap between the date when the first state (North Carolina in 1928) was first declared disease free and the date when the last (California 1940) achieved control. And as A. E. Wight of the US BAI noted, the entire campaign required only 24 years.<sup>78</sup>

Bovine tuberculosis, of course, was not truly eradicated in the US by the end of 1940. Given the precision of the tests pushing the reaction rate below 0.5 percent would have been increasingly expensive. (As noted above, the proportion of positive results that were false rose as the actual prevalence of the disease fell.) Enforcement efforts flagged after the beginning of the Second World War, and localized outbreaks of the disease cropped out periodically over the post-war years. The most notable example occurred in Michigan in the early 1950s.<sup>79</sup> By early the 1960s bovine TB was sufficiently controlled that the USDA decided to suspend the continuous tuberculin-testing of cattle to rely on a more targeted effort. During the testing era the USDA had also developed a tracking system that allowed the government to identify the shippers of all cattle processed at federally inspected slaughterhouses. When an inspector found an infected bovine or swine carcass, a veterinarian was dispatched to test all the cattle on the

---

<sup>78</sup> Wight et al., "Tuberculosis and Its Eradication," p. 245. On the other hand, a 12-year gap was roughly on par with the lag in the diffusion of the mechanical cotton harvester between progressive California and the backward Southeastern states.

<sup>79</sup> US Agricultural Research, *Why Tuberculosis in Livestock is Increasing* (May 1960); Smith, *Conquest*, p. 48.

originating farm. As of 1965 the slaughter, surveillance, and tracing system became the sole line of defense against bovine TB.<sup>80</sup>

The bovine tuberculosis eradication campaign led to a trend reversal in the proportion of infected animals condemned at the slaughterhouse. Figure 6 graphs the share of cattle and swine slaughtered at meatpacking plants under federal inspection that was retained due to evidence of tuberculosis infection.<sup>81</sup> Given the operation of the eradication effort, it is important to distinguish between the share of all cattle and the share in cattle excluding known reactors (from both the numerator and denominator). Between 1907 and 1917, the percent of all cattle carcasses retained for the disease rose from less than 0.5 percent to over 2.5 percent. Additional data show the percent of cattle carcasses condemned and tanked rose from 0.3 percent to about 0.5 over this period. The rise in the share of swine retained for TB (including both bovine and avian forms) was even greater than that for cattle. The anti-bovine TB campaign had complicated effects of the share of tuberculous carcasses entering the meat supply. Due to the destruction of reactors, the carcasses retained due to TB actually increased as a share of the total cattle slaughtered, at least up until 1926. Focusing on the population excluding known reactors, the share of retained carcasses steadily declined after 1922. The share of swine retained also began to fall after 1925, conferring important benefits to the meat-packing sector.

### **Opposition to the Eradication Program**

The campaign to eradicate bovine TB generally had support from the veterinary community, meat packers, and an assortment of public health officials. But the enthusiasm among farmers was far from universal and opposition by cattle growers did much to delay early efforts. This opposition represents an intriguing case of resistance to technical change but should not be viewed as knee-jerk Ludditism in light of the public and increasingly compulsory nature of the program. As noted above, cattle that tested positively often showed no outward signs of illness leaving farmers convinced that their cattle were healthy and of no threat to anyone. In

---

<sup>80</sup> National Research Council, *Livestock Disease Eradication*, pp. 36-39. Government programs are often characterized as permanent and ever expanding. The program against bovine tuberculosis does formally continue today, and it did serve as the model for the early campaigns against avian tuberculosis and brucellosis. But the cost-cutting shift of the TB program from periodic testing to detection at the slaughterhouse and tracing back to the herd represents a case where the government largely “just faded away” after the problem was solved.

<sup>81</sup> Circa 1908, federal officials inspected about one-half of the meat slaughtered in the US; by the 1920s, the fraction had increased to two-thirds.

addition to threatening the farmer's livelihood should the cattle test positively, opposition stemmed from the misguided beliefs that tuberculin injections could cause bovine abortions or reduce milk flow. In an age before the dangers of TB were fully recognized, even the pasteurization of milk was controversial. As an example in 1908 Chicago passed an ordinance requiring pasteurization of milk sold in the city and tuberculin testing of cows supplying the milk. This incited a storm of protest among dairy operators and milk dealers that lasted through the mid-1910s. The tuberculin testing campaign started modestly in Wisconsin in 1917 with the appropriation of \$18,000 (matched by the federal government) for tuberculin testing of breeding cattle in Waukesha County, but "organized opposition" obtained an injunction that derailed the program.<sup>82</sup> This was one of the first of a long line of injunctions that local farmers obtained, but in most if not all cases the courts eventually ruled on behalf of the government.

Cases concerning the testing and destruction of tuberculosis cattle reached the Supreme Courts of Minnesota (1925), Iowa (1926, 1927, 1928, 1930, 1932), Nebraska (1927, 1928, 1930, 1931), Michigan (1929), Ohio (1929, 1930, 1931), Washington State (1932), Illinois (1934), California (1937) and Court of Appeals of New York (1928), among others. In every case, the laws (apart from minor technicalities) were upheld. The underlying reasoning was that the laws protected against disease and, under the common law, cattle infected with contagious diseases were public nuisances and could be summarily destroyed by public officials without compensation to their owners. The courts held this destruction was not a taking of private property for public use (as requisitioning cattle for military would be), but an abatement of a public nuisance (akin to destroying a burning building to put out a fire).<sup>83</sup>

Nationwide organizations split on the issue of bovine TB eradication. The American Farm Bureau and its state and county chapters along with the National Grange lobbied for the program while the Farmers Union and the so-called American Medical Liberty League often mounted stiff opposition that retarded acceptance in many states.<sup>84</sup> As another example, while officials of the American Meat Packing Institute, headed by Oscar Meyer, lobbied Congress in

---

<sup>82</sup> Smith, *Conquest*, p. 13.

<sup>83</sup> Tobey, *Legal Aspects*, pp. 77-81. In *Lawton v. Steel* (1894), 152 U.S. 136, 38 L. Ed. 338, 14 S. Ct. 4999, the US Supreme Court affirmed that the government police power "is universally conceded to include everything essential to the public safety, health and morals, and to justify the destruction or abatement, by summary proceedings, of whatever may order be a public nuisance (including) the destruction of a house falling to decay or otherwise endangering the lives of passers-by;... the slaughter of diseased cattle; the destruction of decayed or unwholesome food."

<sup>84</sup> Smith, *Conquest*, pp. 13, 17-19, 29-31.

support of the program, the Farmers' Protective Association, led by Joseph Cope, leveled sharp criticism in the 1928 hearings on the Department of Agriculture Appropriation for 1929.<sup>85</sup> One apparent consequence of the debate was that Congress increased the indemnity limits in the following year.

Perhaps the most prominent critic of the eradication program was Senator Carter Glass who when he was not gearing up to revamp America's financial institutions, fancied himself as a gentleman farmer and a defender of the common man against an abusive and bungling government. In January 1922 a veterinarian representing the State of Virginia tested Glass's prized herd of Jerseys and proclaimed that two heifers were positive and had to be destroyed. By Glass's account he quarantined the two animals in question and then respectfully asked for a retest on the grounds that his herd had been declared clean a year earlier, his animals had had no contact with other animals that might have infected them, and he thought that the veterinarian representing the state was incompetent. Glass went into great detail on this latter point, charging the state agent had administered a doubtful test in an unsanitary way, had misrepresented who he actually was, and was high handed in testing the animals "without notice to the owner of the herd and without the opportunity to him or to his local veterinarian to observe the test...." (p.2). When the Virginia State Veterinarian, Dr. Ferneyhough refused Glass's request and reportedly insulted Glass in the process, the senator embarked on a personal jihad against the good Doctor and eventually against the entire eradication program. In a 31-page tirade published as a US Senate document in 1928, Glass recounts how he was stonewalled and ignored, how his private veterinarian was banned by the state of Virginia for having the audacity to retest Glass's animals, how state officials threatened and tampered with his expert witnesses, how state officials summarily rejected the recommendations for a retest by Federal BAI officials and numerous other impartial experts, and how when one of the condemned heifers was put down after an accident laboratory tests found no signs of tuberculosis. A few the headlines embodied in Glass's attack will give a hint of the extent of his anger: "Unprofessional Conduct Charged," "Menace to Property Rights," "Wanton Official Obstinacy," "The Bunglers Revealed," "The Conspiracy Broadens," "Arbitrary Bureaucracy Rebuked," "An End to Official Terrorism," and "Deception and Despotism." In 1927 Glass won a court case ordering the retesting of the

---

<sup>85</sup> US House of Representatives, *Agricultural Appropriation Bill 1929*, 70th Cong., 1<sup>st</sup> Sess (Washington, DC: GPO, 1928), pp. 1110-40. See also Congressional Record, 70<sup>th</sup> Cong, 1<sup>st</sup> Sess., 28 May 1928, pp. 10343-44.

remaining heifer, which passed. Not satisfied Glass charged that the entire testing program was build on a set of unproven and speculative theories and gathered expert testimony from around the world questioning whether humans could even contract the bovine type of tuberculosis.<sup>86</sup>

The most publicized grassroots opposition took place in Cedar County, Iowa where local radio station helped to incite what came to be known as the “Iowa Cow War.” After brewing for some time the controversy erupted on 9 March 9 1931 when up to 1,000 farmers confronted state veterinarians and 20 sheriffs sent to begin testing on farms near Tipton, Iowa. When state officials subsequently arrested two of the ringleaders, protesters organized a march on the state Capital. On March 19 about 1,500 protesters, egged on by leaders of the Iowa Farmers’ Union, showed up, but with no obvious effect. In other incidents, officials and reporters were roughed up and cattle were stampeded to avoid testing. For all the hoopla, these incidents represented the exception rather than the rule. By the time of the protests, a significant number of Iowa counties had already been certified and 75 percent of the cattle in Cedar County had already been tested. The situation quieted down after the state assured farmers that they could use accredited veterinarians of their own choosing to administer the tests.<sup>87</sup> Opposition then shifted from Iowa to South Dakota and California.<sup>88</sup>

An unusual mixture of events, including the organized opposition of dairymen, delayed the implementation of the eradication program in California. Health officials had long recognized that California suffered from serious problems with bovine tuberculosis. In 1899, the State Veterinarian observed: “tuberculosis exists to an alarming degree among the dairy herds of this State, especially in and around the larger cities where... from 50 to 90 per cent (of the dairy cows)... are affected with the disease.”<sup>89</sup> The State Legislature slowly moved to address the problem. In 1915, it enacted a “Pure Milk” law prohibiting the sale of raw milk from cows that had not passed the tuberculin test. In 1921, legislation allowed state cooperation with the federal

---

<sup>86</sup> US Senate, *Tubercular Infection in Animals: Methods of Treatment of Breeders and Dairymen in the Enforcement of Regulations for the Elimination of Bovine Tuberculosis* 70th Cong. 1st Sess. Senate Doc. No. 85 (Washington, DC: GPO, 1928).

<sup>87</sup> Myers, *Half Century*, pp. 228-29; Smith, *Conquest*, p. 45. Vivian Wiser et al., “100 Years of Animal Health, 1884-1994,” *Journal of NAL Associates* 11:1/4 (Jan.-Dec. 1986), p. 40.

<sup>88</sup> When enacted in the late 1920s, the South Dakota program evolved to contain a number of safeguards including the farmer’s right to appeal the appraisals and request retesting of reactors. The catch regarding retesting was that the owner was liable for the full cost of hiring the three-member board of veterinarians if they determined the diagnosis was correct. LEXIS-NEXIS.

<sup>89</sup> California Department of Agriculture, *Monthly Bulletin* (Aug. 1931), p. 510.

accredited herd and area plans, but given constitutional qualms, provided no state indemnities.<sup>90</sup> This meant the state's farmers were ineligible for federal money as well. As a result, relatively few cattle owners volunteered for the test-and-slaughter program. By the late 1920s, the biennial BAI surveys began to highlight the enormous gap between the eradication efforts in California and most of the rest of the nation, including Oregon and Washington. The California Bovine Tuberculosis Law of 1929 allowed for state payments for the first time, although it appropriated no money for this purpose. Its real intention was to create the basis for a "friendly" case before the California Supreme Court. That august body ruled on 21 April 1930 that state indemnities were constitutional.<sup>91</sup> A constitutional amendment passed in the November 1930 election explicitly allowed indemnities. Legislation in 1931 provided for the first state money, making California, traditionally a trendsetter, the next to last state to participate fully in the federal eradication effort.<sup>92</sup>

However, the program's troubles continued. Under the depression-era budget shortfalls, state funds soon dried up. The indemnities paid over the mid-1930s came solely from the federal emergency money. (State funding resumed after 1937.) Perhaps, more critically, an "organized group of dairymen in certain counties (including Fresno, Kings, Merced, and Stanislaus) resorted to injunctions and court actions in an endeavor to obstruct and hinder tuberculin testing progress."<sup>93</sup> The participating San Joaquin valley farmers were largely of foreign descent.<sup>94</sup> Although these farm groups repeatedly received temporary injunctions, the higher courts always ruled against their claims that the eradication efforts were illegal. The court challenges proved so numerous and persistent through the mid and late 1930s that the State Attorney general appointed a fulltime deputy to handle the bovine tuberculosis cases.<sup>95</sup> The stalling tactics did have potentially devastating ramifications. C. U. Duckworth argued in 1939 that the livestock sanitary officials of the "remaining states talked very seriously a year ago of asking the federal government to quarantine California because were not showing enough results... California can

---

<sup>90</sup> California Department of Agriculture, *Monthly Bulletin* (Nov.-Dec. 1921), p. 661.

<sup>91</sup> California Department of Agriculture, *Monthly Bulletin* (Sept.-Oct. 1930), p. 673.

<sup>92</sup> M. E. McDonald, "Tuberculosis Control in California," in *Proceedings of 65<sup>th</sup> Convention of the California Fruit Growers and Farmers*, Dec. 1932, p. 22.

<sup>93</sup> California Department of Agriculture, *Monthly Bulletin* (Oct.-Dec 1935), p. 366. See also USDA Appropriations Hearing 1935, p. 143. Also see, "Here and There with Jack Klein," *California Cultivator*, 30 Nov. 1940, p. 644.

<sup>94</sup> "Supreme Court Rules Against Dairymen," *California Cultivator*, 5 Aug. 1937, p. 437; Smith, pp. 31, 48.

<sup>95</sup> California Department of Agriculture, *Monthly Bulletin* (Nov. 1938), p. 488.

not stand this black eye much longer...(We) should be ahead rather than lagging behind....”<sup>96</sup> California’s experience in controlling animal diseases, including foot-and-mouth disease, brucellosis, and bovine tuberculosis, calls into question popular generalizations, promoted by historians such as Kevin Starr, about the state’s preeminent role as a vanguard of progress over the twentieth century. In these important cases many California dairymen had to be dragged kicking and screaming into the twentieth century even when faced with overwhelming evidence that the lives and health of consumers and producers were at risk and with the full knowledge that the eradication program was working well in other states.

It is important to emphasize that for all the opposition the general pattern in all states was for most farmers to support or at least abide by the programs policies. In fact, for many years in the 1920s there were waiting lists for farmers who wished to participate and in many states the federal indemnity appropriations were exhausted well before the fiscal year ended.<sup>97</sup>

### **Cost and Benefits of the Eradication Campaign**

Before the anti-TB campaign began to check the spread of bovine tuberculosis, the disease represented, in the words of the 1916 USDA Yearbook (p. 25), “the greatest problem confronting the live-stock industry of the country.” The damage the disease wrought was not only limited to cattle. In addition, bovine TB also infected pigs fed on contaminated milk or cattle feces or raised in the proximity of infected cattle. As a result, meat inspectors retained and condemned thousands of swine carcasses each year. (Given the high incidence of transmission of the disease from cattle to pigs, it was most economical to control its spread among swine indirectly, by pursuing its eradication in the cattle population). And more importantly, bovine TB harmed tens of thousands of humans annually exposed when producing or consuming contaminated meat and dairy products.

A 1908 analysis by A. D. Melvin of the BAI estimated the annual direct losses to the food production sector at \$23 million.<sup>98</sup> Circa 1914, the US Secretary of Agriculture updated the

---

<sup>96</sup> California Department of Agriculture, *Monthly Bulletin* (Jan. 1939), pp. 44, 47.

<sup>97</sup> US House of Representatives, Agricultural Appropriation Bill 1928, 69<sup>th</sup> Cong. 2d Sess., House Report No. 1619 (Washington, DC: GPO, 1927), p. 99.

<sup>98</sup> Melvin, “Economic Importance,” p. 101. Melvin estimated the total rate of infection on 1 Jan. 1908 at 3.5 percent, based on the conventional guesses of 1 percent for beef cattle and 10 percent for dairy cows and numbers on their 1908 population shares.

number to \$25 million.<sup>99</sup> Bovine TB was the third leading animal disease in terms of losses to the farm sector, ranking behind hog cholera (\$75 million per year) and Texas fever and cattle ticks (\$40 million), but ahead of contagious abortion (\$20 million). The total direct losses from all animal disease amounted to \$212 million per year. In the aftermath of the inflation associated with the First World War, the USDA estimated the annual cost of bovine TB was at least \$40 million.<sup>100</sup>

All of the above estimates referred to only losses to animal production and exclude effects on human health. The estimates were also largely static and failed to capture the dynamic implication of the contagion. As J. A. Kiernan and L. B. Ernest observed in 1919, “Had the spread of [bovine] tuberculosis been allowed to continue at the same rate that it progressed from 1907 to 1917, the disease would undoubtedly have exacted an annual toll from the live-stock

---

Livestock producers did not generally suffer financially if meat inspectors condemned animals they had raised because cattle sales were not conditions on post-mortem inspections. Packers did typically pay less on average for animals from areas where TB rates were known to be high. An earlier 1908 conservative USDA estimate put the financial losses totaled \$14 million per annum. (1908 Yearbook of Agriculture, p. 33.)

<sup>99</sup> Edward B. Mitchell, “Animal Disease and Our Food Supply,” in USDA, 1915 *Yearbook of the Department of Agriculture, 1915* (Washington, DC: GPO, 1916), p. 160, entire article is pp. 159-72.

<sup>100</sup> John A. Kierman and Alexander E. Wight, *Tuberculosis in Livestock: Detection, Control, and Eradication*, Farmers Bulletin 1069 (Washington, DC: GPO, 1919), p. 2.

Melvin “Economic Importance,” (pp. 101-04) undertook a detailed although largely conjectural estimate of the losses caused by TB. His estimated total annual loss was \$23 million, which he considered conservative. He included four categories of losses: (1) condemnation of diseased animals at slaughterhouses, \$3.83 million; (2) depreciation of live animals, \$8.05 million; (3) reduced quantity of milk output, \$10 million; and (4) losses in breeding, the remainder. Many of the figures were clearly guesstimates and the conceptual basis for the depreciation category is unclear. It is sensible to include reductions in animal values due to disease-induced weight loss and contagion to new stock, but it is double-counting to include reductions in value arising from capitalizing the losses from condemnation and lower milk output. Also note that the most valuable category, losses to milk output, include only quantity effects, not quality effects.

The earlier USDA number of \$14 million was reported by Melvin in a prior version of the paper presented at an international tuberculosis congress in Washington, DC on 29 September 1908. A. D. Melvin, “The Economic Importance of Tuberculosis of Food-Producing Animals,” *Transactions of the Sixth International Congress on Tuberculosis* Vo. 4, Pt. 2 (Philadelphia: William F. Fell, 1908), pp. 501-11. The \$10 million estimate was based on the same calculations but assuming milk output losses totaling \$1.15 million. Given that the wholesale value of milk in 1909 was approximately \$974 million and the TB losses were about 1 percent (10 percent production loss for the 10 percent of the dairy cattle infected), the initial estimate is an order of magnitude too small. Little wonder that Melvin changed the loss estimates to \$10 million for milk and \$23 million in total for the BAI 1908 *Annual Report* published in 1910.

Taking into account the growth in the number of cattle and hogs and increases in their nominal prices, the \$25 million estimate for 1914 and \$40 million estimate in 1919 are actually more closely related to the early, lower estimate. Over the 1908-14 period, the total value of cattle and hogs rose by 1.75 times; over the 1908-18 period, by 2.97 times. This is in line with the 1.79 (=25/14) and 2.85 (=40/14) growth in losses using the \$14 million base. The bottom line is that the \$40 million loss figure for 1918-19 appears a lower-bound estimate for the losses to the food production sector.

producers of this Nation of one hundred million dollars” and “reputation of the United States as a producer of high-class cattle and swine would have received an irremovable stigma.”<sup>101</sup>

Although there have been a number of attempts to compare the costs and benefits of the program, none that we know of meets conventional standards of economic analysis. Typically, the costs of the programs are measured as the cumulative undiscounted sum of nominal government expenditures. (For the 1917-62 period, this sum totals about \$420 million.) Besides its problems with the treatment of interest rates and inflation, this approach completely ignored the substantial costs that farmers bore through uncompensated losses for slaughtered reactors. We can get closer to the mark if we estimate the net losses to farmers, deflate the annual combined public and private costs to reflect inflation, discount using a constant 3 percent real interest rate, and cumulate back to specific reference year, say 1918.<sup>102</sup> According to our calculations, the discounted cost of the program over the 1917-62 period in real 1918 dollars was \$258 million dollars (adjusting for inflation this would amount to about 3 billion dollars in 2000). Of this, the federal government contributed about 31 percent, the state governments 54, and farmers 15 percent. Broken down in another way, real discounted costs in the eradication phase (1917-40) accounted for \$219 million (about 85 percent of the spending) with the maintenance phase (1941-62) making up the remainder. The peak activity was in the 1930s (with 46 percent of total spending) and the 1920s (with 36 percent). At the assumed 3 percent real interest rate, the \$258 million investment in the program was equivalent to borrowing with the promise to repay 7.7 million 1918 dollars each year in perpetuity.

The benefits of the program to the livestock sector may be measured in two ways. We begin by accepting the BAI conservative estimate that the disease cost the US animal industry \$40 million per year in 1918. Assuming the losses declined proportionally with the infection rate in the cattle population, the present value (in discounted 1918 dollars) of benefits from reducing the prevalence of bovine TB over the 1918-62 period was \$1,280 million. Of this, \$488 million

---

<sup>101</sup> J. A. Kiernan and L. B. Ernest, “The Toll of Tuberculosis in Live Stock,” in USDA, *Yearbook of the Department of Agriculture, 1919* (Washington, DC: GPO, 1920), pp. 280-81. The entire article is pp. 277-288. They also estimated that at this time the premium paid for non-reacting cattle (relative to untested stock) was \$10 for grade animals and \$25 for purebreds (pp. 284-85).

<sup>102</sup> To estimate the net losses to farmers, we use the difference between the appraised value and the sum of the salvage value and the government indemnities. We restrict these losses to the animals on which indemnities were claimed, rather than all reactors or all reactors slaughtered. The assumption is that for other animals, the difference between the appraisal and salvage values was too small to justify claiming the indemnity. The results do not fundamentally change under alternative assumptions. Our estimates also exclude the cost of private veterinary services and of disinfecting contaminated premises (the later also carried benefits that are also omitted).

accrued in the eradication phrase. To this, we can add the benefits from preventing the infection rate from rising as the contagion spread through the animal population. Assuming a contagion rate of 5 percent per annum in the absence of the program, we estimate the TB eradication campaign saved an additional \$1,940 million over 1918-62 period (of which \$404 million accrued between 1918 and 1940). Thus the total discounted benefits were roughly \$3,180 million. The estimated benefits according to the first approach would be equivalent to a perpetuity paying \$38.4 million per year. Combining in the benefits from the second approach would generate a perpetuity paying \$98.7 million per year. Thus for the farm sector alone the annual benefits ranged between five and twelve times the annual costs. Indeed, the annual data reveal that the cumulative benefits of the program exceeded its cumulative cost from 1919 on, almost from its very beginning.

Although the net benefits of the eradication program in the farm sector were impressive, they represent a small part of the story, because the most important benefit was reducing human suffering and death. To evaluate the effects of the eradication campaign on human health, it is desirable to include the effects of milk pasteurization. Tuberculin-testing and pasteurization were twin approaches to reducing human infection by bovine tuberculosis through milk. The first approach attempted to prevent the entry of tubercle bacteria into the milk supply and the second sought to destroy those harmful bacteria that do enter before the milk is consumed. It is difficult to evaluate their effect separately, but we know jointly they led to “almost eliminating human disease due to *M. bovis* by the 1940s.”<sup>103</sup> According one authority, by 1942 there had been such a marked decline in the incidence of “the bovine type infection in man that medical experts have stated it is practically impossible to find such cases for the clinical instruction of medical students.”<sup>104</sup>

Although any such analysis raises as many questions as it answers, we can offer a provisional estimate of the value of the saving in human life from the effective elimination of bovine tuberculosis in humans in the US. In Appendix 1, we develop estimates of the reduction in deaths in the US in 1940 due to the efforts against bovine TB. Assuming that 10 percent of

---

<sup>103</sup>National Research Council, *Livestock Disease Eradication*, p. 9. Even if one assumed that the eradication program had no effect on the spread of TB to humans through the milk supply, the remaining impact of the program in reducing human infections via reducing the direct infection of farm workers and meat handlers and via safer meat supplies would have still been substantial. Roberts, “A Retrospective Assessment,” pp. 294-95.

<sup>104</sup>John R. Mohler, “Infectious Diseases of Cattle,” pp. 315-447 in V. T. Atkinson et al., *Special Report on Diseases of Cattle*, revised edition, 1942 (Washington, DC: GPO, 1942), p. 376.

TB cases in 1900 were due to the bovine form of the disease, then in the absence of the pasteurization and eradication efforts, roughly 20 to 25 thousand more deaths would have occurred in 1940. Now consider estimates of the value of life at the start of the campaign. Irving Fisher placed the figure at \$8,000 per TB death in 1908 dollars whereas the Kim-Fishback value of life estimate is closer to \$8,500 in the purchasing power of the period.<sup>105</sup> Taking Fisher's lower figure (and converting it to the 1918 purchasing power employed above) implies the value of preventing 20 to 25 thousand deaths totaled between \$256 and \$320 million per year, several times larger than the annual saving to the livestock industry. It is clear that the benefits were huge and primarily outside the agricultural sector.

## **Conclusion**

The campaign to eradicate bovine TB highlights the importance of biological learning in the period before 1940, specifically the technical innovations arising out of the "Germ Theory of Disease." Prior to the 1890s, stock raisers generally could not tell if animals were infected with bovine TB and had no idea what caused the disease or how it was transmitted. With the advent of the new theory, knowledge rapidly advanced. In 1882, Robert Koch identified that the specific bacillus that caused the human form of the disease and in 1890/92, Koch and Bang discover a way to test for both human and bovine TB. In the mid-1890s, Theobald Smith's experiments distinguish between the bovine and human types of the bacillus. Authorities discovered the disease was far more widespread in livestock than they had presumed, although they did not figure out how to cure it or how to vaccinate against it. Through local efforts such as the Washington, DC project, US animal health officials discovered that if they got rid of the infected animals and cleaned up dairies and stockyards, the disease did not return so long as it was not reintroduced. Within three decades of this revelation that the disease was "eradicable," bovine TB was effectively brought under control across the entire United States.

The campaign also illustrates the problem of limiting the analysis of agricultural regulations and technological changes to their effects on the agricultural sector. Although the rate of return of the eradication campaign to the farm sector alone more than justified the effort, the spillovers effecting human health were the dominant part of the story. In contrast with the

---

<sup>105</sup> Kim and Fishback, "Institutional Change," p. 811.

human form of tuberculosis, infections of the bovine strain were largely preventable for several decades before the introduction of effective chemotherapies. However prevention required political resolve, an extensive educational campaign, the unflinching use of the state's police power, enormous costs, and perhaps most importantly a great deal of common sense to develop incentive compatible rules of the game and an efficient and respected bureaucracy. While most of the world waited, the United States (along with Canada) adopted an aggressive testing and eradication program shortly after the technology, embodied in the simplified intradermic tuberculin test, became available. The results were undeniable. Beginning with dairy herds serving many populous areas and with prized breeding stock, the state-federal program dramatically and ruthlessly slashed the bovine infection rate with an immediate spillover on human health. In contrast to the more cautious policies followed in Europe, the aggressive US campaign spared hundreds of thousands of Americans from contracting tuberculosis over the period between 1917 and 1950.

It is paradoxical that the US was so much more aggressive than most other countries. The federal system, over most of this period, was characterized by greater fragmentation and a far weaker central government than most European states. The American philosophical bent towards pragmatism and compromise was also at variance with the idealistic, almost utopian, goal of complete eradication of the disease. The compulsory nature of the area plan also ran against American voluntaristic traditions. One might suspect that the relatively centralized states of Europe, with their less democratic political systems, established bureaucracies, and centralized research establishments might have been able to respond more rapidly to the evolving state of scientific knowledge. As we note above, part of the reason for the foot dragging in Europe surely stemmed from the greater severity of the problem Europeans faced and thus the greater costs that they had to incur. However it is important to note that once most western European countries commenced an eradication program after WWII, they did move very rapidly. This was in part because they had the benefit of the American model to guide them—this offered the assurance that the eradication would in fact work.<sup>106</sup> It would be a mistake to subscribe to the standard public choice explanation that Washington bureaucrats were more adept rent-seekers

---

<sup>106</sup> There was a more direct American influence in the US zone in occupied Germany where US forces encouraged eradication efforts. Was there more than a simple cost-benefit calculation at work in explaining the aggressive American approach to bovine TB? Perhaps the American eradication campaign represents a variant of Aymatra Sen's argument that democracies, in spite of the apparent clumsiness of the political process, historically have responded much more effectively than dictatorships to ward off the impact of famines.

than their European counterparts. There is little evidence that the BAI officials were trying to monopolize power or otherwise seeking economic rents for their own benefit. To the contrary, as we note above the BAI leaders consistently encouraged the growth of state control and financing of the programs and once the problem was reasonably under control moved on to other issues.

The enthusiasm for the eradication program transcended political boundaries. The federal program began under Woodrow Wilson's watch, thrived under Harding, Coolidge, and Hoover's presidencies, and was significantly expanded during Roosevelt's New Deal.<sup>107</sup> Precedent-setting legislation that authorized less ambitious eradication programs to control other animal diseases dated back to 1870s, and legislation requiring tuberculin testing of imported cattle dates to the McKinley regime. With few exceptions both Republican and Democratic governors and Republican and Democratic dominated state legislatures supported the testing and slaughter of cattle. The legality of the condemnation and slaughter of millions of animals was systematically upheld by both conservative and liberal state and federal courts that ruled that the confiscation of sick animals did not constitute a "taking," but under the common law, was the abatement of a public nuisance.<sup>108</sup> It is difficult to consider that in today's litigious environment, and with protests by animal-rights advocates, that such a policy would be possible. Quarantining and killing a small number of animals to prevent the entrance of a new contagion appears different from slaughtering a large number of animals to uproot a disease that has already established a presence.

The story of the TB eradication effort also sheds light on the nature and sources of the technological changes that transformed American agriculture. The standard treatment of productivity growth in pre-1940 US agriculture emphasizes the importance of mechanical innovations to the virtual exclusion of biological (that is, non-mechanical) technological changes. This view dominates the agricultural economics and international economic

---

<sup>107</sup> For example, in 1928, Calvin Coolidge requested a supplemental appropriation to fund fully paying the increased indemnities. US House of Representatives, *Communication from the President of the United States Transmitting Supplemental Estimate of Appropriation for the Department of Agriculture Amounting to \$500,000 for the Fiscal Year 1930 for an Additional Amount for the Eradication of Tuberculosis in Animals*, 70<sup>th</sup> Cong., 2d Sess., Document No. 476 Dec., 14, 1928. And as early as 1917, Herbert Hoover was behind the program and was "very strongly in favor of eradicating tuberculosis immediately in the dairy district." US House of Representatives, Committee on Agriculture, *Tuberculosis among Live Stock: Hearings before the House Conferees on the Agricultural Appropriation Bill*, 65th Congress, 2nd session, 6 April 1918, p. 17; and M. L. Requa to J. R. Mohler, October 1917, Records of the BAI, Central Correspondence, 1913-1953, Entry 3, Box, 337, National Archives.

<sup>108</sup> Tobey, *Legal Aspect*, p. 81-82.

development literatures as reflected by the writings of Hayami and Ruttan and numerous others, and it is standard fare in most economic history textbooks. For the animal sector, most historical analysis of productivity has focused on quantities—the pounds of milk per cow, the size of slaughtered animals, feed-output conversion ratios, etc. and has totally ignored the changes in quality. The concentration on milk-to-cow output ratios has led to the ridiculous, but ubiquitous, claim that the biological revolution in milk production was largely a post WWII phenomenon. The reality is that the milk sold in 1900 very likely could kill you (it in fact was responsible for hundreds of thousands of deaths a year in the United States) and the milk sold in 1940 was more or less of a similar quality to the milk sold in the twenty-first century. This finding coupled with our findings on the importance of biological innovations for the production of a number of other agricultural commodities suggests that the standard paradigm should be scrapped.<sup>109</sup> A more accurate perspective is that for most sectors of the agricultural enterprise, the pre-World War Two era witnessed biological innovations that equaled or surpassed the importance of new mechanical technologies. The relative importance of biological innovations may have increased after the war with the green and genetic revolutions, and but the rate of mechanical innovation also increased in this era.

---

<sup>109</sup> Alan L. Olmstead and Paul W. Rhode, “The Red Queen and the Hard Reds: Productivity Growth in American Wheat, 1800-1940,” *Journal of Economic History* 62:4 (Dec. 2002): 929-66.

## Appendix 1

This appendix estimates the savings in lives resulting from the anti-bovine TB campaign. We will start with a crude calculation and then consider refinements. All of the calculations assume the eradication and pasteurization efforts reduced the actual bovine rate to virtually zero by 1940. The measured death rate due to TB was 194.4 per 100,000 population in the US in 1900. The US population was 75 million in 1900 and 131.7 million in 1940. Extrapolating the 1900 rate to 1940 (194.4 times 131.7 million) yields 256 thousand TB deaths in 1940. Taking 10 percent of these as due to the bovine form implies the elimination of that form resulted in saving 25.6 thousand lives in 1940. This estimate is admittedly crude because it ignores other forces working to increase or decrease the bovine TB death rate.

We will now refine the estimate by considering two offsetting forces: (1) the probable decline of the bovine TB death rate in line with what was occurring with the non-bovine form, and (2) the likely increase due to the continued spread of the disease among animals in the absence of the eradication efforts. To estimate the expected decline, we need to approximate the reduction of the non-bovine form independent of the changes in the bovine form. We know the total TB rate fell from 194.4 deaths per 100,000 in 1900 to 45.9 in 1940. Assuming the bovine share declined from 10 to 0 percent, the non-bovine death rate in 1940 fell to 26.7 percent  $((45.9 - 0)/(194.4 - 19.4))$  of its 1900 level. Now suppose that instead of falling to zero, the bovine rate had declined in proportion with this estimated reduction in non-bovine rate. Then in the absence of the eradication and pasteurization programs, the bovine death rate would have fallen to 5.1 per 100,000  $(=19.4 * 0.267)$  and there would have been 6.7 thousand more deaths from bovine TB in 1940.<sup>110</sup> But we also know that in the absence of the eradication effort, bovine TB would have spread further among the cattle and swine population, likely leading to two-to-four times higher infection rate by 1940. Assuming a tripling in the share of animals infected and a commensurate increase in human infection suggests a bovine death rate (after making the adjustment calculated above) of 15.3 per 100,000 in 1940. This implies there would have been 20.2 thousand additional deaths in the US in 1940 in the absence of eradication and pasteurization programs.

---

<sup>110</sup> Because of the high incidence of bovine TB in infants, and the entirely different avenues of contracting the bovine infection, it is unlikely that the bovine death rate would in fact have fallen as much as the fall in the fall in the death rate from the non-bovine TB in the absence of the agricultural programs.

Figure 1: Comparing Values Per Head With Appraisal, Salvage, and Payments

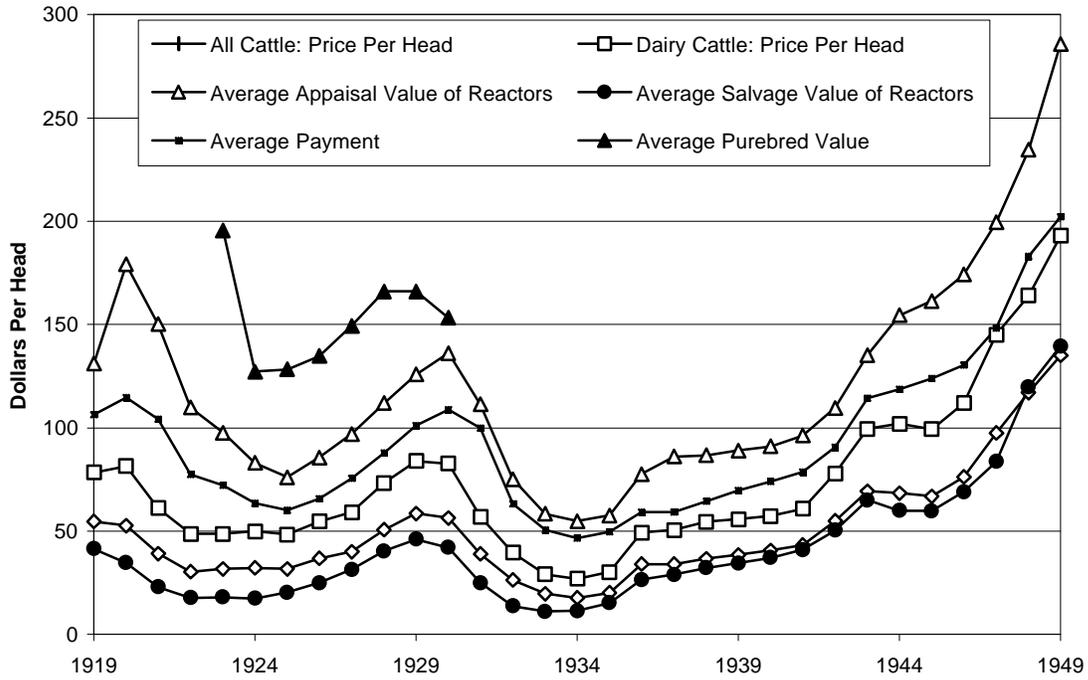
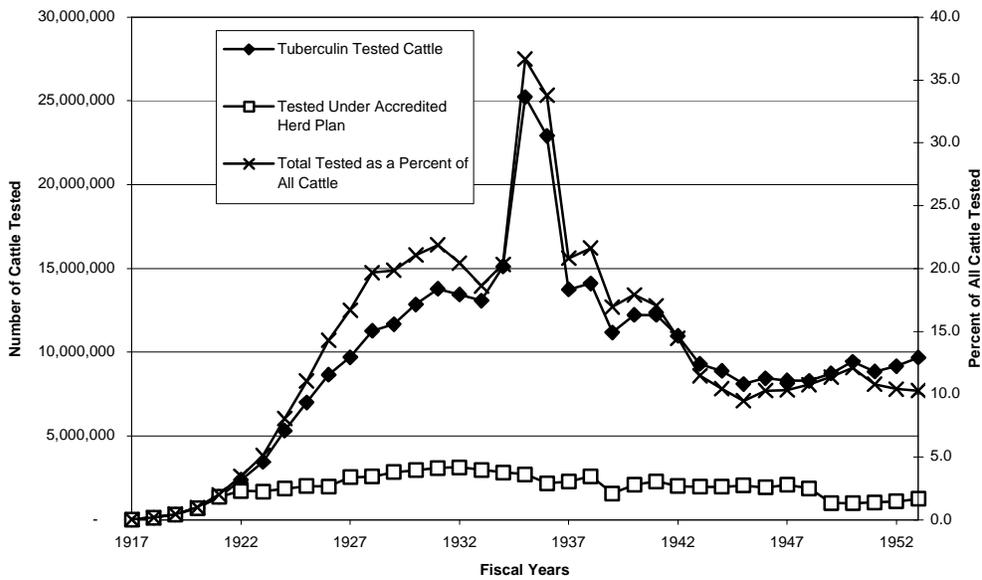
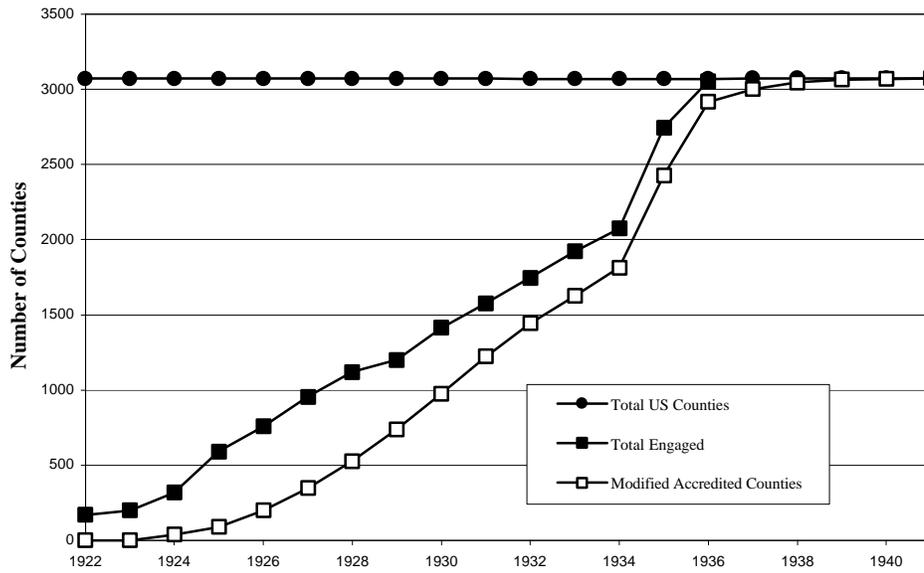


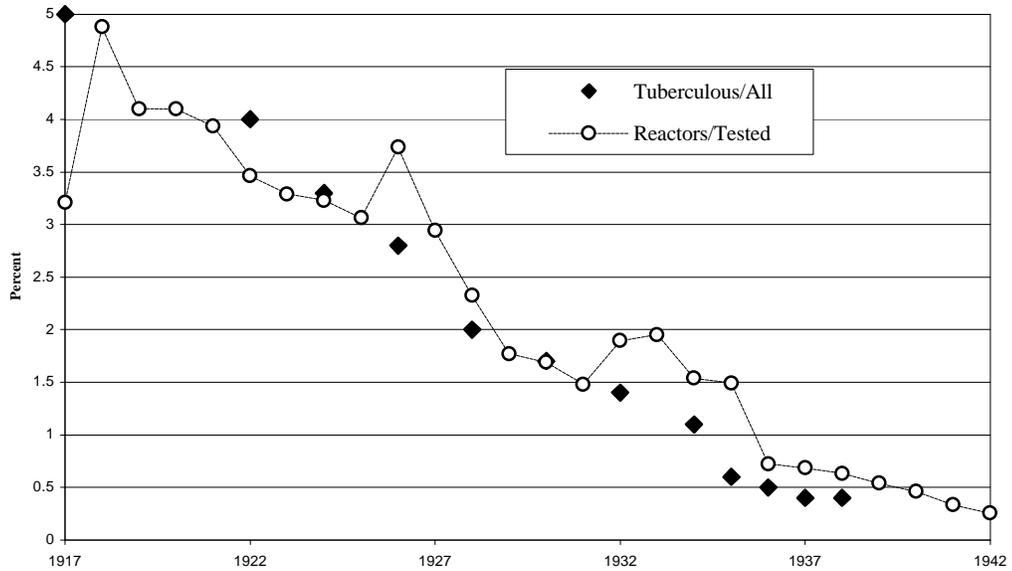
Figure 2: Tuberculin Test Given Annually, 1917-1953



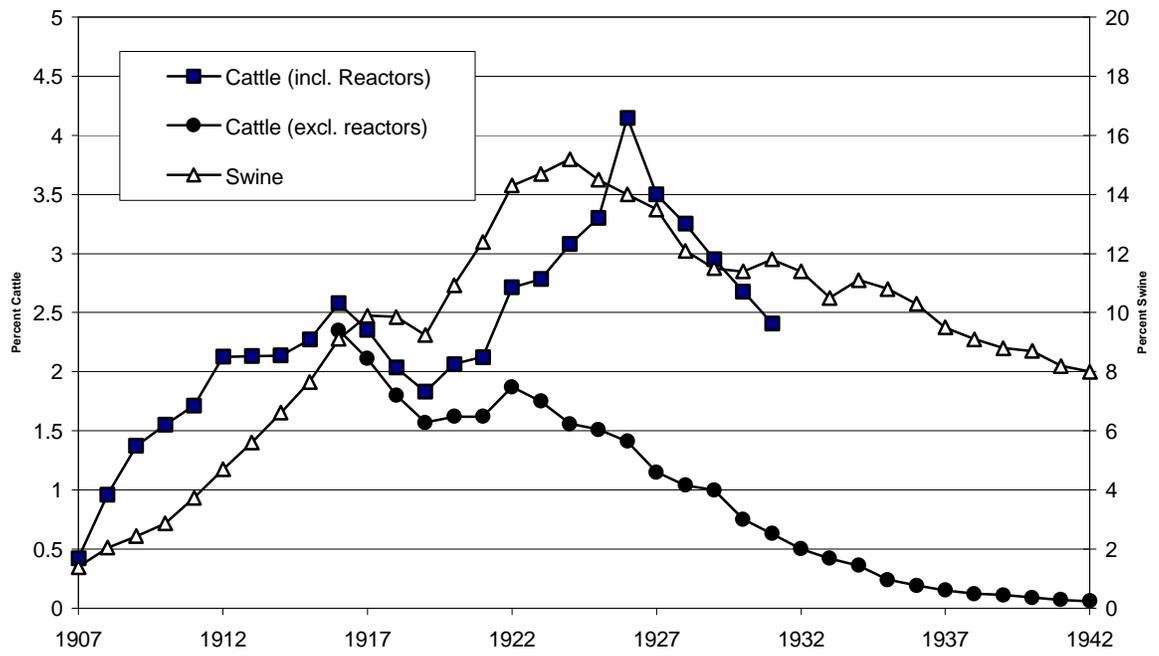
**Figure 3: US Counties Involved in TB Eradication Area Plan**



**Figure 4: Extent of TB Infection Among Cattle, 1917-42**



**Figure 6: Percentage of Cattle and Swine Slaughtered Under Federal Meat Inspection Retained due to Tuberculosis**



**Table 1: Timeline of “Germ Theory of Disease” for Tuberculosis**

1865	Jean-Antoine Villemin demonstrated tuberculosis is contagious.
1882	Robert Koch discovered the tubercle bacillus by developing a staining technique allowing detection of <i>Mycobacterium tuberculosis</i> .
1884	First TB Sanatorium established in US.
1890	Robert Koch developed tuberculin, which he hopes to use as a vaccine.
1890-91	Tuberculin used as diagnostic test by Bernhard Bang of Denmark and W. Gutmann of Russia.
1892	Leonard Pearson introduced tuberculin testing to Pennsylvania.
1895	Commercial milk pasteurization machines introduced.
1898	Theobald Smith distinguished between bovine and human forms ( <i>M. bovis</i> and <i>M. tuberculosis</i> ).
1901	Robert Koch mistakenly argued bovine tuberculosis posed little threat to humans.
1902	M. P. Ravenel isolated the bovine microorganism from a child with tuberculous meningitis.
1904	National Association for the Study and Prevention of Tuberculosis the first national US, voluntary health organization aimed at conquering a specific disease, was founded.. (Becomes American Lung Association in 1973.)
1906-09	US BAI instituted “test-and-slaughter” program in District of Columbia. Over next decade, they determine bovine TB is “eradicable.”
1906-19	Calmette and Guerin of Institut Pasteur develop BCG vaccine which was first used in humans in 1921 with limited effectiveness.
1909	Chicago became first city to mandate milk pasteurization (except for milk from cows passing the tuberculin test.)
1917	State-Federal Cooperative Bovine Tuberculosis Program initiated.
1940	California becomes last state to be fully accredited as a modified area.
1943	Selman Waksman discovered the first drug, streptomycin, that could kill TB bacteria.

Table 2: Regression Results Explaining Extent of Testing over FY 1917-49 completed by FY1930.

	Reactor 1930/49	Tests 1930/49	Reactor 1930/49	Tests 1930/49
Farmer's Loss 1919	-0.2273 (0.0649)	-0.1782 (0.0396)		
Farmer's Loss 1928			-0.4263 (0.06083)	-0.1773 (0.06071)
Share Reacting	-15.37 (5.472)	-8.868 (3.335)	-18.29 (4.370)	-11.82 (3.199)
Dairy Share	0.2759 (0.1018)	0.0600 (0.0620)	0.3240 (0.1156)	0.0863 (0.0729)
Cattle Price	0.148 (0.2662)	0.1408 (0.1623)	0.1261 (0.2889)	0.2168 (0.2076)
Constant	60.52 (12.64)	(32.14) (7.71)	61.07 (14.13)	24.10 (10.13)
R-squared # obs	0.434 48	0.467 48	0.478 48	0.306 48

Robust standard errors in parenthesis.

#### Summary Statistics

Variables	Obs.	Mean.	Std. Dev.	Min.	Max.
Reactors 1930/49	48	56.94	20.64	1.92	91.34
Tests 1930/49	48	25.09	12.98	3.81	55.12
Farmer's Loss 1919	48	56.34	37.90	0.01	100
Farmer's Loss 1928	48	28.19	22.97	-1.14	100
Share Reacting 1949	48	0.94	0.84	0.08	3.80
Dairy share 1920	48	55.3	29.0	5.26	96.9
Cattle Price 1920	48	56.92	17.51	23.09	102.24

Figure 5

1924

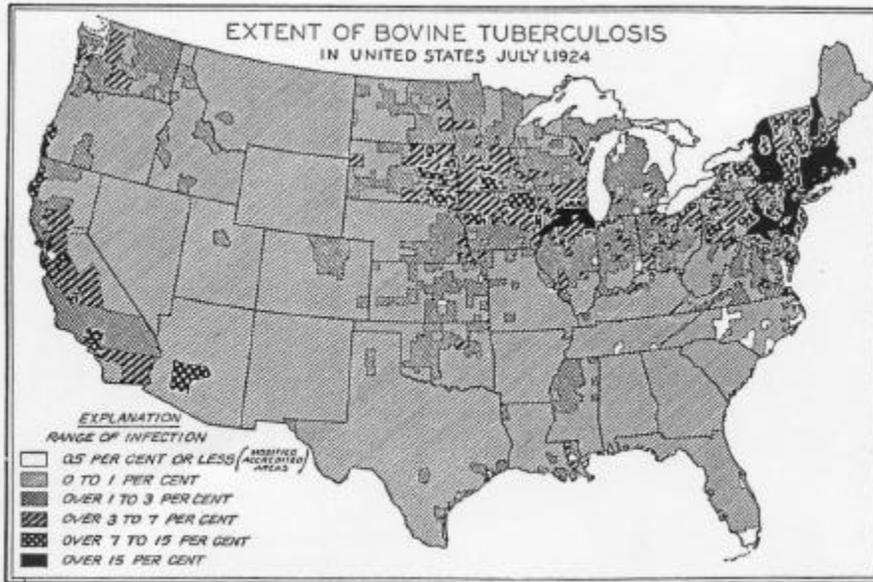


FIGURE 20. Map of the United States, showing distribution of tuberculosis among cattle on July 1, 1924. The darker the area the higher the incidence of tuberculosis. Note the few counties in white; this indicates that they have received the modified accredited rating, having reduced tuberculosis among the cattle to one-half per cent or less. (Courtesy U. S. Bureau of Animal Industry.)

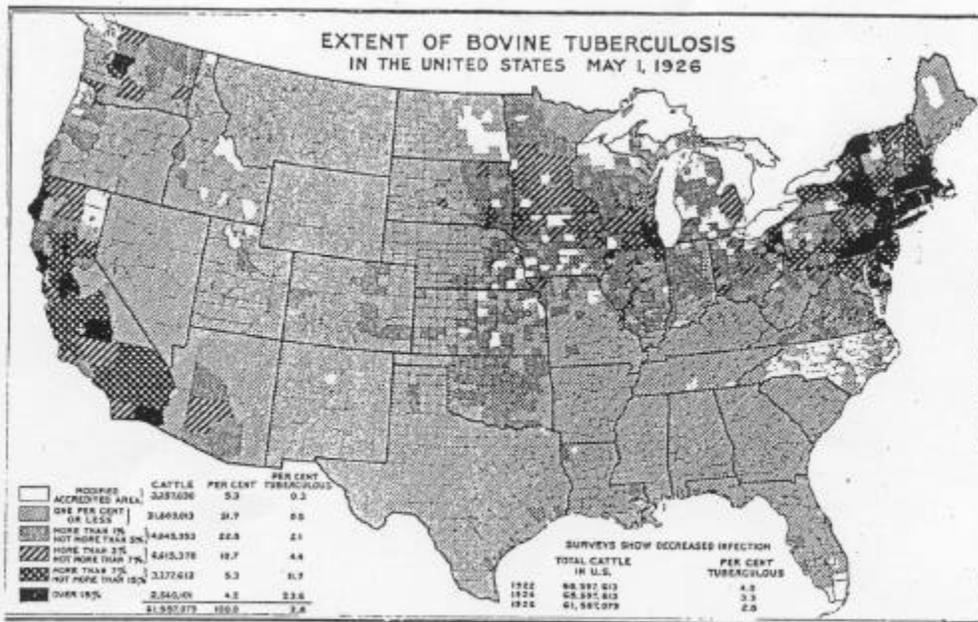


FIG. 24.—Distribution of bovine tuberculosis and the degree of infection in various portions of the United States. Results of surveys conducted in 1922, 1924, and 1926 indicate a gradual decline in the extent of this disease.

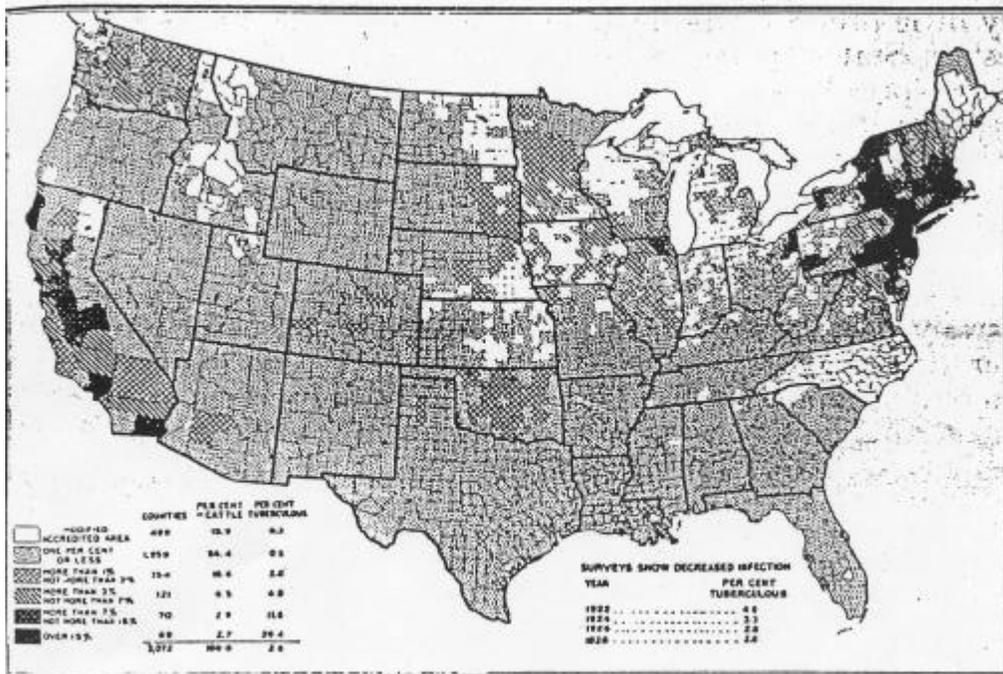


FIG. 2.—Extent of bovine tuberculosis in the United States, May 1, 1928

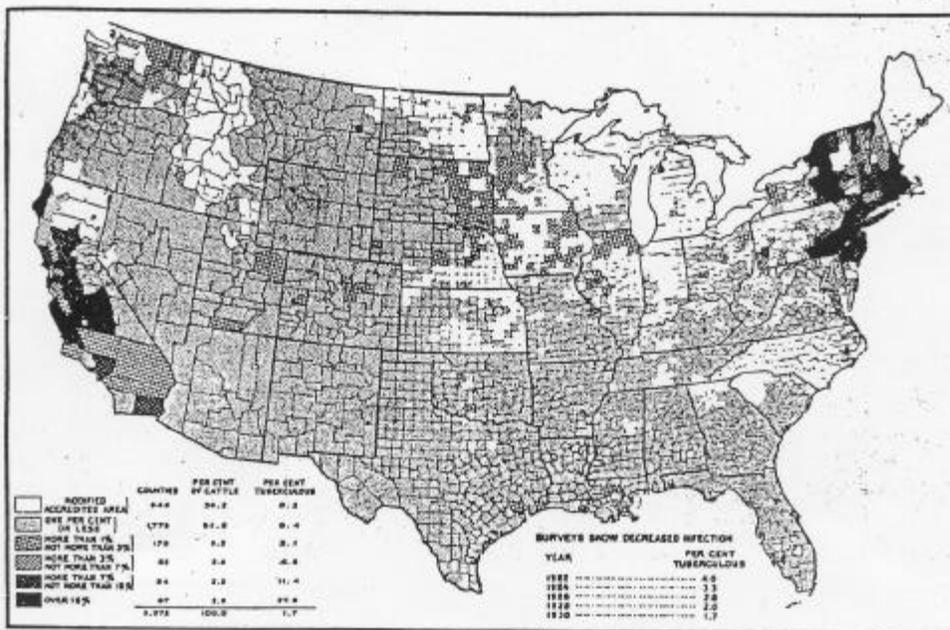


FIGURE 2.—Extent of bovine tuberculosis in the United States, May 1, 1930

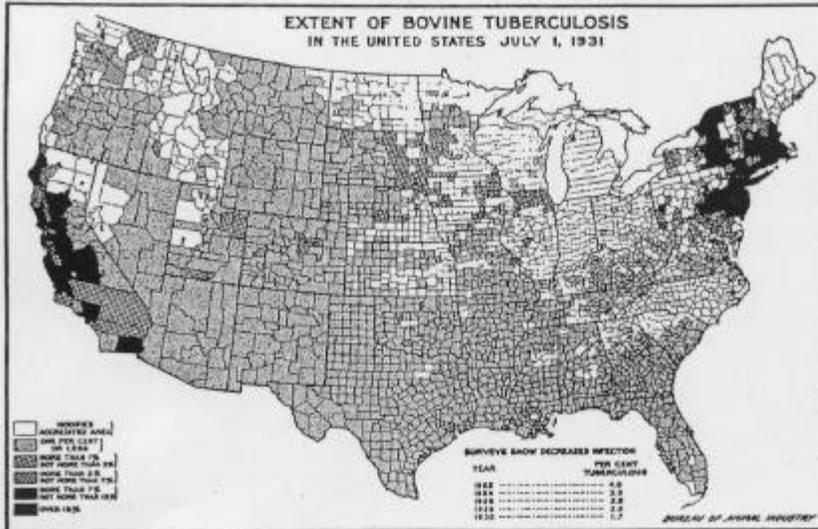


FIGURE 21. Map of the United States showing distribution of tuberculosis among cattle on July 1, 1931. The white portions of the map are modified accredited areas, signifying 0.5 per cent or less of tuberculosis among cattle, as shown by tuberculin tests. On July 1, 1931, modified accredited areas included 1223 counties, parts of 2 counties, and 50 towns. The development portrayed on this map has occurred since July 1923, when 17 counties in 4 states were designated as the first modified accredited areas. (Courtesy U. S. Bureau of Animal Industry.)

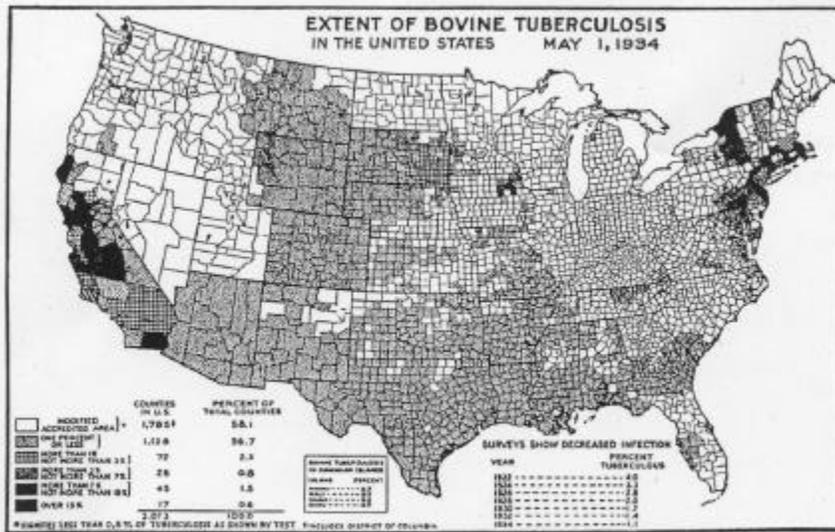


FIGURE 22. Map of the United States showing distribution of tuberculosis among cattle on May 1, 1934. The white portions of the map are modified accredited areas, signifying less than 0.5 per cent of tuberculosis among cattle, as shown by tuberculin tests. On May 1, 1934, the modified accredited areas included 1,784 counties, parts of 2 counties, and 76 towns in Vermont. The development portrayed on this map has occurred since July 1923, when 17 counties in 4 states were designated as the first modified accredited areas. (Courtesy U. S. Bureau of Animal Industry.)

1935

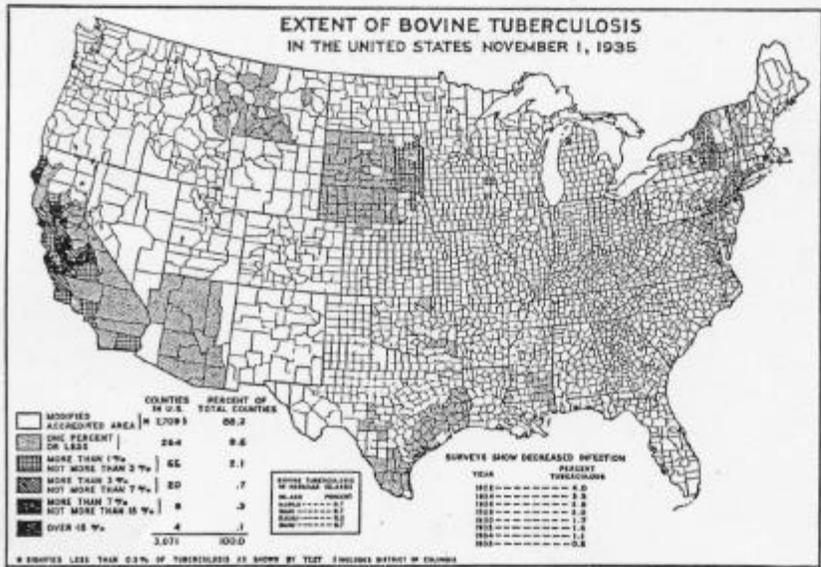


FIGURE 23. Map of the United States showing distribution of tuberculosis among cattle on November 1, 1935. The white portions of the map are modified accredited areas, signifying less than 0.5 per cent of tuberculosis among cattle, as shown by tuberculin tests. On November 1, 1935, the modified accredited areas included 3709 counties, parts of 4 counties, 105 towns in Vermont, and one municipality in Puerto Rico. The development portrayed on this map has occurred since July 1923, when 17 counties in 4 states were designated as the first modified accredited areas. (Courtesy U. S. Bureau of Animal Industry.)

1937

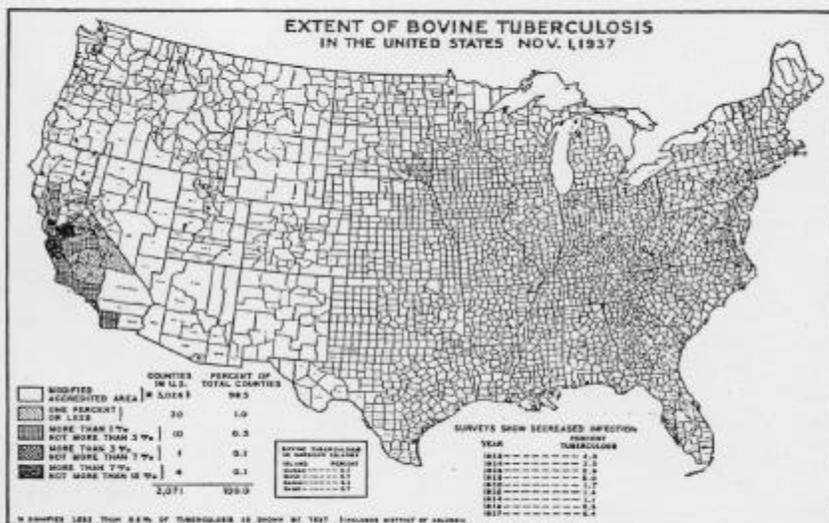


FIGURE 24. Map of the United States showing distribution of tuberculosis among cattle on November 1, 1937. The white portions of the map are modified accredited areas, signifying less than 0.5 per cent of tuberculosis among cattle, as shown by tuberculin tests. The modified accredited areas included 3,026 counties or 98.5 per cent of the total 3,071 counties in the United States. Note that the unaccredited counties are limited to South Dakota and California. (Courtesy U. S. Bureau of Animal Industry.)

