Economic Research Service
U.S. DEPARTMENT OF AGRICULTURE

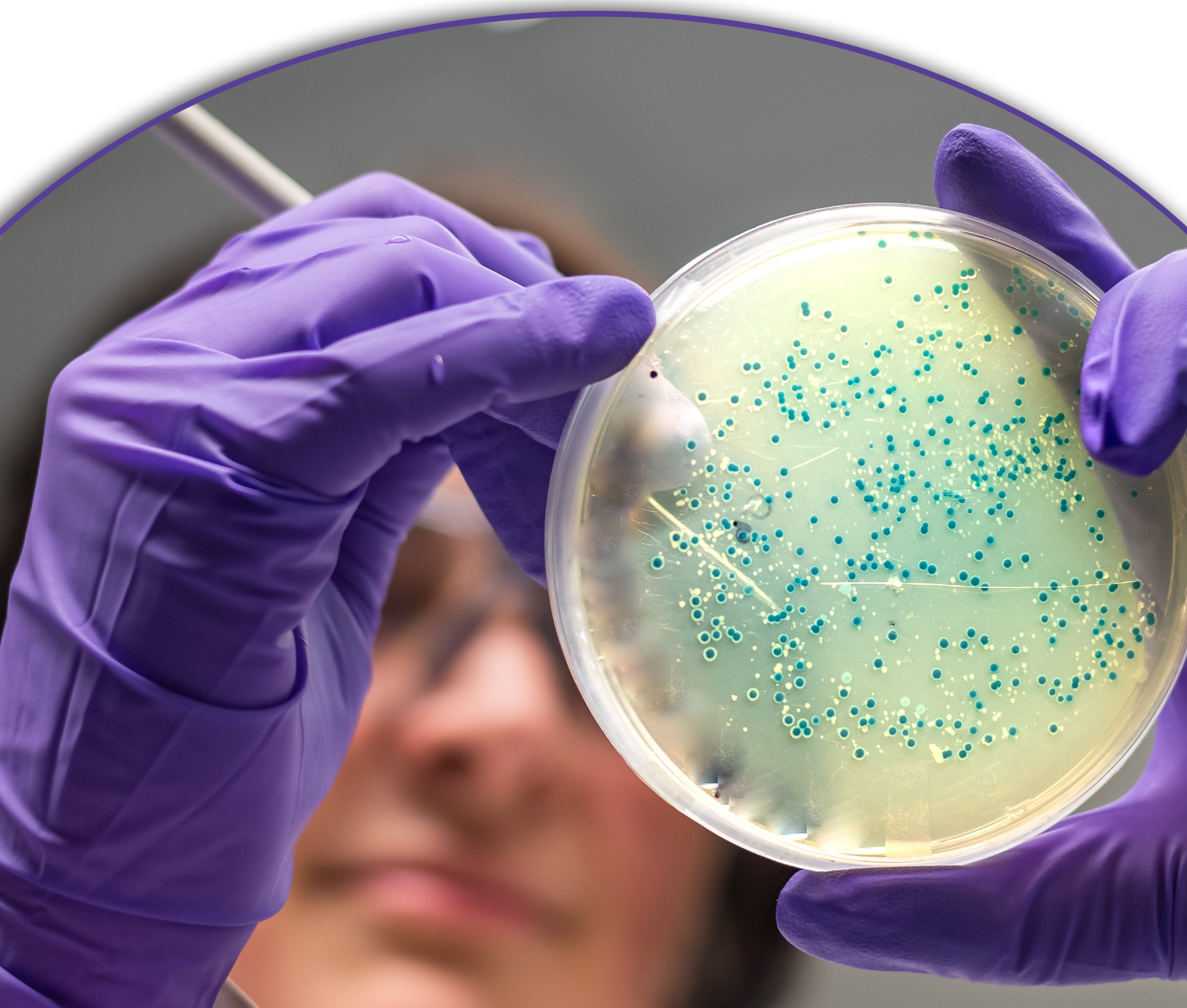
**Economic Research Service**

Economic Research Report Number 297

November 2021

# Updating Economic Burden of Foodborne Diseases Estimates for Inflation and Income Growth

Sandra Hoffmann and Jae-Wan Ahn



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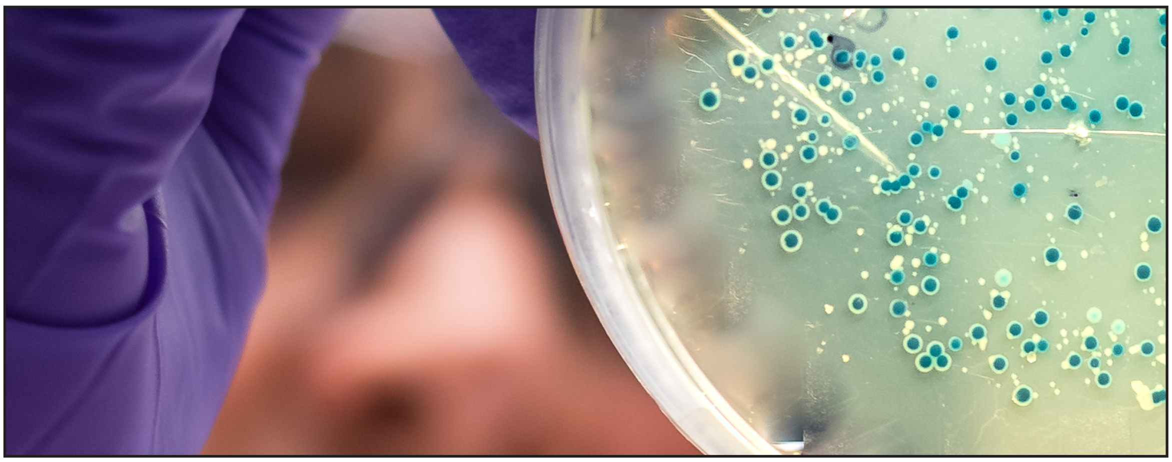

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## Abstract

This report updates the USDA, Economic Research Service's (ERS) 2013 estimates of the economic burden for the 15 leading foodborne pathogens for inflation and income growth to 2018. USDA, ERS estimates of the economic burden of foodborne diseases include the costs of medical care, the value of lost productivity due to illness-induced absences from jobs, and the economic burden of premature deaths from foodborne illness. These estimates reflect the impact on consumers, not producers. Inflation and income growth result in a higher economic burden of foodborne illness, even holding constant disease incidence and health care use. We found that in 2018 dollars, the economic burden of these pathogens was $17.6 billion, an increase of about $2 billion, or 13 percent, over the 2013 USDA, ERS estimate of $15.5 billion for the same 15 pathogens. Overall inflation from 2013 to 2018 was 7.8 percent, and real per capita gross domestic product (GDP) growth was 8.8 percent. This means the value of preventing these foodborne illnesses increased by about 5 percentage points more than overall inflation and 4 percentage points more than income over the 5-year period. This paper also explores the role of price inflation and income growth in driving changes in the economic burden of these illnesses.

**Keywords:** foodborne illness, pathogen, inflation, cost of illness, economic burden.

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## What Is the Issue?

Estimates of the economic burden of foodborne disease are used to inform public policy discussions, research, and the general public about the economic impact of foodborne diseases. Since the mid-1990s, the USDA, Economic Research Service (ERS) has provided estimates of the economic burden of U.S. foodborne diseases. The latest USDA, ERS estimates were for 2013 (Hoffmann et al., 2015). These estimates cover 15 major foodborne pathogens that account for over 95 percent of cases with an identifiable pathogen cause.

Since 2013, there has been substantial inflation in medical care prices. In particular, the prices that hospitals charge for inpatient stays rose by 25 percent between 2013 to 2018. In comparison, overall inflation rose 7.8 percent. Income, as measured as real per capita Gross Domestic Product (GDP), rose by 8.8 percent.

This report updates USDA, ERS cost of foodborne illness estimates for inflation and income growth. These estimates include three broad cost components: the costs of medical care, the value of time lost from work due to the illnesses, and value individuals place on preventing deaths from foodborne illnesses.

## What Did the Study Find?

Our analysis provides several insights into how the cost of foodborne illnesses in the United States changed in response to inflation from 2013 to 2018.

1. Inflation caused the USDA, ERS cost of foodborne illness to rise from $15.5 billion in 2013 to $17.6 billion in 2018. The top five pathogens—*Salmonella, Toxoplasma, Listeria*, norovirus, and *Campylobacter*—accounted for 90 percent of 2018 costs (summary figure)

2. Increases in the price of hospital care drove 74 percent of the increase in the total cost of medical treatment for foodborne illnesses from all 15 pathogens.

3. The value of preventing deaths accounted for 83 percent of the cost of foodborne illnesses from the 15 pathogens in 2013. As a result, the change in the value of preventing deaths also drove most of the change in the cost of these foodborne illnesses from 2013 to 2018.

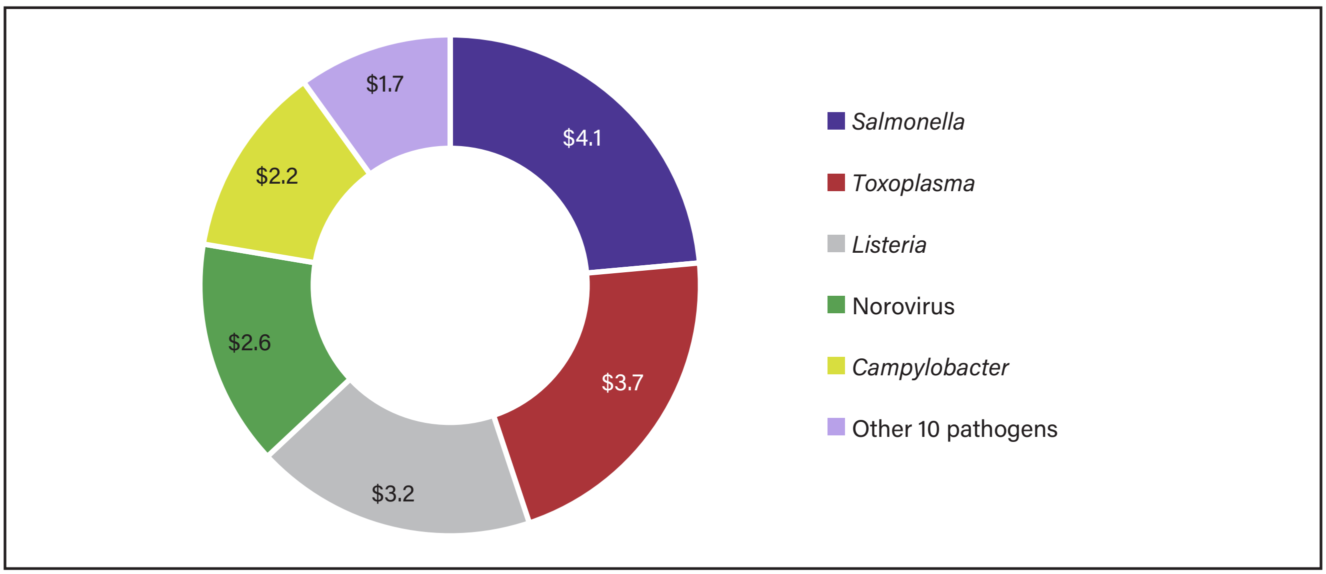
## How Was the Study Conducted?

This study updates USDA, ERS estimates of the cost of 15 major foodborne illnesses for inflation experienced from 2013 to 2018 (Hoffmann et al., 2015). This update reflects only the influence of price and income changes and not changes in the annual number of illnesses or the amount of health care services used. Our estimates are based on Centers for Disease Control and Prevention (CDC) U.S. foodborne illness incidence estimates for 2011, the latest year available, and on previous USDA, ERS modeling of health care use (Scallan et al., 2011a; Buzby et al., 1996; Frenzen et al., 1999; Frenzen et al., 2005; Hoffmann et al., 2012; Hoffmann et al., 2015).

USDA, ERS estimates the social cost of non-fatal illness as the sum of the cost of medical treatment and wages lost because people could not work while they were ill.  This is an underestimate of the full social cost of preventing these illnesses (Hoffmann and Anekwe 2013). We use Consumer Price Indexes (CPIs) from the Bureau of Labor Statistics (BLS) to adjust these estimates for inflation. As is widely done in social cost analysis, we use people's willingness to pay to prevent deaths as a measure of the social cost of deaths. Following standard practice, we update this value for both price inflation and income growth.

Detailed 2018 estimates for each of the 15 pathogens are available in the Cost Estimates of Foodborne Illnesses Data Product on the USDA, ERS website. The website also has a detailed explanation of how to adjust USDA, ERS cost of illness estimates for inflation and income growth, as well as a spreadsheet with information needed to make these adjustments for other years (USDA, ERS Cost Estimates of Foodborne Illnesses, 2021).

**Economic burden of the top 15 major foodborne diseases in the United States in 2018 dollars**




Source: USDA, Economic Research Service calculations.

# Updating Economic Burden of Foodborne Diseases Estimates for Inflation and Income Growth

## Introduction

Government, industry, researchers, and consumers expend considerable resources trying to reduce foodborne illness (Congressional Research Service, 2020; Gardner, 2020; Markets and Markets, 2020; Flynn, 2019; Runvik, 2017). To best marshal these resources, policymakers and food safety managers need to know the value of prevention efforts to society, as well as their costs and effectiveness.

Food safety policy and management may focus on one or multiple pathogens. Food safety policymakers and managers must also make decisions about how to prioritize efforts and resources across multiple pathogens. Examples of each abound. The U.S. Department of Agriculture, Food Safety and Inspection Service (FSIS) and U.S. Centers for Disease Control and Prevention (CDC) currently see reducing foodborne *Salmonella* infections as a priority because of its high health burden and because illness numbers have not dropped in recent years (USDA-FSIS, 2020; CDC, 2019). Improving on-farm produce safety has been a priority for both producers and the U.S. Food and Drug Administration (FDA) in part because of a series of national Shiga toxin-producing *E. coli* O157:H7 (STEC O157:H7) (formerly known as *E. coli* O157:H7) outbreaks in lettuce and spinach. But scientists and industry are finding produce can harbor several different pathogens, each of which may respond best to different management practices, creating the need to think about priorities (Center for Produce Safety, 2020).

Cost of illness estimates can aid risk-based prioritization across pathogens. Risk-based approaches to food safety management target interventions based in part on information about the relative health impacts of different foodborne pathogens (Koutsoumanis and Aspridou, 2016; FDA/Center for Food Safety and Nutrition, 2017). Governments and industry have long based decision on the relative risks of different pathogens and foods. This practice is increasingly a formal requirement. The Food Safety Modernization Act of 2011, the first major revision of FDA's food safety statutory authority since the late 1930s, requires risk-based approaches to food safety regulation and management (FDA, 2018). Economic burden estimates provide a comparable measure of health impacts across pathogens that have widely varying health impacts and provide a means of assessing the relative value of alternative interventions.

To help inform food safety policy discussions and management decisions, since the mid-1990s the USDA, Economic Research Service (ERS) has provided estimates of the economic impact of major foodborne infectious diseases on the U.S. public (Buzby et al., 1996; Frenzen et al., 1999; Frenzen et al., 2005; Hoffmann et al., 2012; Hoffmann et al., 2015). In 2013, USDA, ERS expanded its estimates to cover 15 major foodborne pathogens (Hoffmann et al., 2015). These 15 pathogens account for more than 95 percent of illnesses, hospitalizations, and deaths from major foodborne diseases in the United States (Hoffmann et al., 2015; Scallan et al., 2011a). USDA, ERS plans to update these estimates roughly every 5 years and as the CDC updates national foodborne disease incidence estimates. USDA, ERS also maintains an online data product with pathogen-specific disease outcome models and economic burden estimates to facilitate the use of these estimates (USDA, ERS Cost Estimates of Foodborne Illnesses, 2021).

Estimates of the economic burden of foodborne illness draw on information about the costs of hospitalizations, outpatient visits, and drugs, as well as information about price inflation and income growth (Hoffmann, 2012). There is a long-standing concern in the United States about health care costs rising faster than overall economic growth (Fuchs, 2012; Meyer, 2019; Sisko et al., 2019). In recent years, this has been mostly due to rising prices rather than increases in the use of medical services (Morse, 2020; HCCI, 2020; Fuchs, 2012; Meyer, 2019).

The purpose of this paper is to update USDA, ERS estimates of the economic burden of foodborne disease for inflation and income growth from 2013 to 2018 and to examine differences in their effects across pathogens. Simultaneously, we are updating the online USDA, ERS cost of foodborne illness data product (USDA, ERS Cost of Foodborne Illness Estimates, 2021). This data product provides background documentation on how USDA, ERS estimates were developed; a history of this research at USDA, ERS; and detailed spreadsheets for each pathogen that allow users to modify assumptions and use our work as a basis for their analysis.

These updates reflect only the effect of inflation and income growth, not changes in disease incidence or the quantity of health care services used. The CDC is currently working on updates of their national foodborne disease incidence estimates (see box "Health outcomes from foodborne disease."). Future research will revise disease outcome modeling and health care utilization. In the interim, these updates for inflation and income growth provide a more realistic assessment of the current value of preventing foodborne illnesses relative to the value of other goods and services. The report also helps provide a clearer understanding of how rising prices affect the economic burden of foodborne diseases.

## Health outcomes from foodborne disease

Annual foodborne disease incidence is the number of foodborne illnesses in a population during a year. In 2011, the Centers for Disease Control and Prevention (CDC) published its most recent national estimates of annual foodborne infectious disease incidence from all pathogen sources (Scallan et al., 2011a; Scallan et al., 2011b). Foodborne disease incidence estimates were developed by integrated modeling using a wide range of information. This is a major modeling research effort. The CDC updates these estimates periodically and is currently working on revising the 2011 estimates (Scallan et al., 2011a, 2011b; Meade et al., 1999).

The CDC estimates that U.S. residents experience 47.8 million foodborne illnesses annually (Scallan et al., 2011a; Scallan et al., 2011b). These cases include 9.4 million illnesses due to 31 major foodborne diseases for which the pathogen cause can be identified, also referred to as "major pathogens" (Scallan et al., 2011a) and 38.4 million others for which the pathogen cannot be identified or "unidentified pathogens" (Scallan et al., 2011b). The severity of these illnesses varies by pathogen. While unidentified pathogens are estimated to cause 80 percent of foodborne illnesses in the United States, these illnesses are generally mild; less than half a percent of these cases result in hospitalization (Scallan et al., 2011b). In contrast, the median hospitalization rate for the major foodborne pathogens is 20.2 percent.

The 15 pathogens included in the USDA, Economic Research Service (ERS) Economic Burden of Foodborne Disease estimates account for more than 95 percent of hospitalizations caused by the 31 major foodborne pathogens (USDA, ERS Cost of Foodborne Illness Data Product, 2019). These pathogens are the focus of most Federal programs designed to prevent the risk of foodborne infectious disease. Mortality rates for illnesses from most major foodborne pathogens are less than 1 percent, but 2 of the 15 pathogens in USDA, ERS estimates have much higher mortality rates (16 percent for *Listeria monocytogenes* and 35 percent for *Vibrio vulnificus)* (Scallan et al., 2011a).

The CDC and State governments also collect surveillance data on diseases caused by pathogens that are commonly foodborne. This can cause confusion. These surveillance data are not disease incidence estimates. The CDC collects data on both outbreak-related cases and on some sporadic cases.[1] Outbreak cases are a relatively small proportion of all foodborne illnesses and are not generally a representative sample of all foodborne illnesses (Ebel et al., 2016). The FoodNet active surveillance program collects data in 10 States on all (not just foodborne) laboratory-confirmed cases of illnesses that can be foodborne but may be due to other exposure routes. FoodNet data is used in the CDC modeling of foodborne disease incidence but is not by itself a measure of disease incidence (Marder et al., 2017).

The CDC views FoodNet as providing an indication of trends in major foodborne illnesses over time. It reports analyzing trends in FoodNet data from 2013 to 2016 and from 2016 to 2019 to conclude the incidence of these nine infections commonly transmitted through food has remained largely unchanged (Marder et al., 2017; Tack et al., 2020).

[1]The Centers for Disease Control and Prevention (CDC) define outbreaks as instances "in which two or more persons experience a similar illness resulting from the ingestion of a common food" (CDC, 2020).

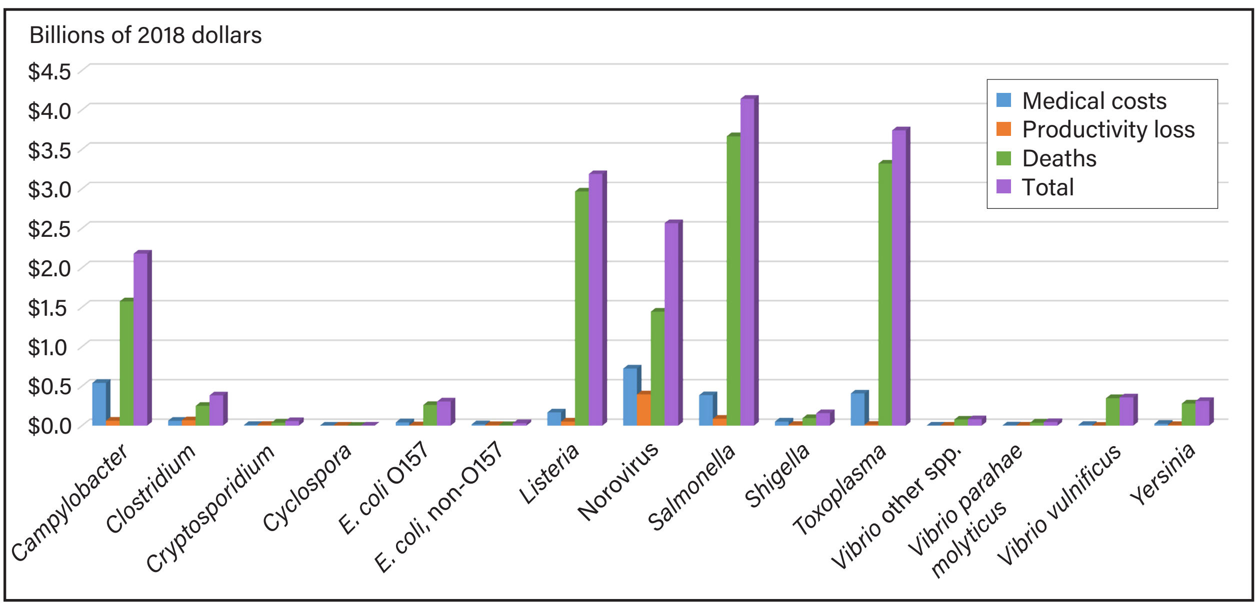
# Methodology for Measuring the Economic Burden of Foodborne Diseases

## Scope and Timing of Updates

We updated pathogens both separately and in aggregate. Food safety is typically managed by pathogen and food/pathogen pairs because pathogens vary in their growth requirements, prevalence, and health impacts (Hoffmann and Taylor, 2005). Some pathogens, such as norovirus and *Listeria,* are ubiquitous in the environment and managed by general hygiene practices (Barclay, 2012). Others, such as *Campylobacter,* have important *Campylobacter*-specific controls on farms and in processing plants (Wagenaar et al., 2006). Some pathogens, e.g., norovirus, cause a large number of relatively mild illnesses. Other pathogens, e.g., *Toxoplasma,* cause a much smaller number of illnesses but have much higher fatality rates. Still others, like STEC O157:H7, can cause serious long-term health impacts. Pathogen-specific estimates are needed to evaluate the worth of pathogen-specific control efforts. Aggregate estimates are used to provide a picture of the importance of food safety efforts relative to other priorities.

USDA, ERS plans to update the economic burden of foodborne disease estimates roughly every 5 years. This schedule balances coordination with CDC incidence estimates, accounting for economic changes and internal staffing resource constraints. The CDC has been producing new U.S. foodborne disease incidence estimates roughly every 10 years (Meade et al., 1999; Scallan et al., 2011a; Scallan et al., 2011b). They are currently revising their 2011 estimates. USDA, ERS will update economic burden estimates to incorporate new disease incidence estimates as they become available. Prices, income, and potentially health care utilization change rapidly enough that it is useful to update health care use, inflation, and income growth more frequently than every 10 years. Yet, some smoothing over the year-to-year variation to see the longer-term picture is desirable. A 5-year interval strikes a balance between these needs.[1]

Figure 1
**Total mean cost of foodborne illnesses in the United States (2018 dollars)**




Source: USDA, Economic Research Service calculations.

[1]We also provide information in the USDA, ERS online data product that others can use to update inflation and income growth annually.

## Economic Framework: Theory and Practice

Estimates of the economic burden of disease are designed to measure the impact of disease on the welfare of individuals, not just the cost of treating illnesses. Individual welfare is influenced by the prices of goods and services and the resources available to obtain them, but ultimately, an individual's welfare is determined by their subjective evaluation of their own well-being.

Economists view an individual's willingness to pay for a good or service as the theoretically appropriate measure of its impact on their welfare. In the case of illnesses, this is individual's willingness to pay to reduce the risk of the illness. In practice, this can be difficult to do. Economists typically examine choices people make in markets to estimate willingness to pay to reduce the risk of illness. When this cannot be done with reliable outcomes, they may conduct surveys. But more often, they draw on information available in markets to develop approximations of willingness to pay to prevent illness.

Willingness to pay to reduce the risk of illness can be thought of as the measure of individuals' decisions about how to use their limited budgets to maximize their individual welfare ("utility"), given that protection of health is only one of the things they want or require. Mathematically, this can be expressed as:

$$\max U_i = f(\underline{x}, pr_i(\text{illness}), pr_i(\text{death}); \text{other}) \text{ subject to individual i's budget limitations} \quad (\text{eq.}1)$$

where $\underline{x}$ is a bundle of non-health related goods and services that individual *i* may want, and $pr_i(\cdot)$ is the likelihood that individual *i* will experience the health outcome in parentheses. This acknowledges that an individual will choose to purchase/secure amounts of goods, services, and levels of health risk reduction that maximize their welfare (utility), recognizing they have a limited budget and there are other things they cannot control. This mathematical relationship guides economic estimation of how much people are willing to pay to reduce the likelihood (risk) of illness.

Using this model, Portney and Harrington (1987) showed that willingness to pay (WTP) to reduce the risk of illness can be broken down into three components:

1. WTP to reduce the risk of nonfatal illnesses, plus
2. WTP to reduce the risk of death from the illness, minus
3. Cost of any preventive actions taken by individuals themselves.

They also showed that willingness to pay to reduce the risk of nonfatal illnesses is the sum of (1) the cost of medical treatment, (2) the value of time lost from other activities while sick, and (3) willingness to pay to avoid the pain and suffering from illness.

Many studies have estimated individuals' willingness to pay to reduce the risk of death, but few have estimated individuals' willingness to pay to reduce the risk of nonfatal illnesses (Cameron, 2014). Willingness to pay to reduce the risk of death has been widely studied by looking at differences in the wages people are willing to accept for jobs with different risks of death (Viscusi, 2014). Because nonfatal illnesses are so diverse in character, it generally has not been feasible to directly estimate willingness to pay for all relevant individual nonfatal illnesses (Cameron, 2014). As shown in the box titled "Complications from foodborne infectious diseases", even foodborne diseases have a wide range of health outcomes. As a result, while the economic burden of disease studies use estimates of willingness to pay for a reduction in risk of death, they typically use an approximation for individuals' willingness to pay to reduce the risk of nonfatal illnesses rather than studies that estimate it directly (Honeycutt et al., 2010).

### Complications from foodborne infectious diseases

Disease incidence does not tell the full story of how foodborne disease burdens people. Most people think of foodborne disease as a few days of diarrhea, as it is in most cases. But, like all infections, it can cause hospitalizations, some with serious complications, and in some cases can result in death. Foodborne diseases caused by different pathogens differ substantially in their hospitalization and mortality rates (Scallan et al., 2011a; Scallan et al., 2011b). From a perspective of understanding the impact of foodborne illness on people's lives and the economic burden of these diseases, it is also helpful to understand other kinds of complications associated with these illnesses.

Hoffmann et al. (2015) provides descriptions of disease outcomes for major foodborne illnesses included in the USDA, Economic Research Service (ERS) economic burden of foodborne illness estimates aimed at a general audience. Many types of infections can leave the original site of infection and become generalized throughout the body resulting in an increased risk of organ failure and death. This is called sepsis and is a serious complication of many foodborne infections (Mangen et al., 2011; Dodd et al., 2017). Some foodborne pathogens have more specific types of complications. Infections from *Listeria monocytogenes* have been associated with an increased risk of meningitis and encephalitis (inflammation of the brain) (Batz et al., 2013). *STEC* O157 is known for causing kidney failure and chronic kidney disease (Batz et al., 2013). Other pathogens increase the risk of chronic intestinal illnesses, chronic arthritis, liver disease, vision impairment and blindness, and permanent mental and physical impairments in infants (Batz et al., 2013).

Research on the chronic outcomes of foodborne illness continues to expand our understanding of the long-term consequences of these infections (Pogreba-Brown et al., 2020; Porter et al., 2016; Batz et al., 2013). Hoffmann and Scallan (2020) report on discussions about chronic consequences of foodborne illnesses during an expert workshop organized by USDA, ERS to inform our efforts to update the disease modeling that underlies USDA, ERS estimates of the economic burden of foodborne disease.

Approximations of willingness to pay to reduce nonfatal illnesses typically are able only to measure the financial losses from these illnesses (i.e., cost of treatment + lost wages). This approximation is often called a "cost-of-illness" estimate (Hodgson and Meiners, 1982). Cost-of-illness estimates underestimate full willingness to pay to reduce nonfatal illnesses because they do not capture the value of avoiding the pain and suffering caused by the illness. In addition, few studies are able to capture expenditures by individuals on preventive actions, though they are believed to be small relative to willingness to pay to reduce risk of death or nonfatal illness.

## USDA, ERS Economic Burden of Foodborne Disease Framework

USDA, ERS estimates of the economic burden of foodborne illnesses in 2013 used "cost-of-illness" estimates for nonfatal illnesses and estimates of willingness to pay to reduce the risk of death for fatalities (USDA, ERS, 2015).[2] As a result, our estimates provided a conservative measure of the public's full willingness to pay to prevent these illnesses. The USDA, ERS report *Making Sense of the Costs of Foodborne Illness* provides a more detailed discussion of these issues and the limitations of different measures of the economic impact of illness (Hoffmann and Anekwe, 2013).

[2]This is why we refer to our estimates as "economic burden" estimates rather than "cost-of-illness" estimates.

Our cost of nonfatal illness estimates includes the cost of several specific types of medical treatment:

- outpatient physician visits
- emergency department visits
- over-the-counter and prescription drugs
- inpatient hospitalizations
- treatment of chronic health outcomes, including dialysis for advanced kidney (renal) disease, and education and support to manage long-term disabilities from foodborne diseases—including vision and hearing impairment, physical disabilities, and mental and learning disabilities.

The types of medical treatment needed and the duration of illness vary by pathogen because severity and complications of disease vary by pathogen (box 2) (Hoffmann et al., 2015; Lampel et al., 2012).

In addition, estimates of the costs of nonfatal illnesses include the value of time lost from other activities because of illness, also called productivity loss. Theoretically, productivity loss includes the value of time lost by the ill person from both paid work and household or leisure activities. It also includes the value of uncompensated time family members spend caring for the sick. The 2013 USDA, ERS cost-of-illness estimates included only lost wages from the ill person. Because they did not capture the value of nonwork activities of the ill person or the value of family care-taking time, they are a conservative measure of productivity loss.

## Updating for Inflation

Economists think of cost as the product of price and utilization of a good or service:

cost = price times the quantity of the good or service used (utilization)

(Nicholson and Snyder, 2012). In this analysis, we adjusted cost only for price inflation. We did not change our 2013 modeling of the quantity of medical care services used or the duration of time away from work due to illness. We refer to changes in price as "inflation" and talk about changes in cost when referring to changes in "price times utilization" over time. Because cost equals price times quantity, when prices rise due to inflation, cost still increases, even if we assume that the quantities of services used have not changed.

To more accurately represent the fact that prices of different goods and services do not all change at the same rate over time, we used different CPIs to adjust the costs of medications, physician and outpatient office visits, emergency room visits, hospitalizations, and medical and other services needed to address chronic outcomes (e.g., special education) (table 1).[3] To remain consistent with past USDA, ERS estimates, we also used the All-Items CPI to update lost wages. After individual components of the cost of illness for a pathogen were updated (e.g., hospitalization costs, physician visit costs, or lost wages), these component costs were aggregated to the pathogen level.

[3]The Consumer Price Indexes (CPIs) estimate how prices paid for different goods or services change over time. Changes in prices over time are referred to as inflation or deflation. These estimates are calculated regularly over time for a wide range of goods and services to provide an understanding of how prices change over time. In the United States, these are maintained by the U.S. Bureau of Labor Statistics (BLS). The price of different goods and services may change at different rates over time, so the BLS maintains multiple CPIs for multiple kinds of goods and services.

Table 1

**Consumer Price Indexes (CPI) used to adjust individual components of ERS Cost of Foodborne Illness (CoI) for inflation***

| CPI Index | ERS CoI component to be converted | Percent change in CPI 2013–2018 |
|---|---|---|
| All items | Average daily earnings or total productivity loss | 7.80 |
| | Medical and special education | |
| | Premature death | |
| Medical care | Chronic end-stage renal disease (ESRD) | 14.00 |
| Physician services | Physician office visits | 7.40 |
| Prescription drugs and medical supplies | Prescription medications | 19.30 |
| OTC drugs | Nonprescription drugs or medications | -2.40 |
| Inpatient hospital services | Hospital admissions | 25.00 |
| Outpatient hospital services | Emergency room and other outpatient hospital visits | 22.30 |
| Per Capita GDP** | Premature Death | 8.80 |

** We use per capita GDP as our income measure. We present the % change in per capita GDP from 2013 to 2018 in this table as a point of comparison to CPIs used in this analysis because it is used in updating our estimates of WTP to reduce fatality risk.

*Source: USDA Economic Research Service, Cost of Foodborne Illness Data Product. CPI indices are from: Bureau of Labor Statistics, Consumer Price Index.

Willingness to pay to reduce the risk of death can be thought of as a measure of individuals' demand to reduce that risk. Demand for any good depends on the prices of all goods and individuals' incomes (Nicholson and Snyder, 2012). Over time, if incomes rise, people may demand more of a good. As prices of different goods change at different rates, people's demand for different goods may also shift. This is also true for people's willingness to pay to reduce the risk of death.[4] As a result, we looked at changes in the price of all goods and income over time to update our estimates of the economic burden of deaths from foodborne illness. Deaths were valued using estimates of the value of a statistical life (VSL), a measure of individual willingness to pay to reduce the risk of death scaled up to represent the U.S. population's willingness to pay to reduce expected annual deaths across the population by one death.

In updating the VSL for income growth and overall price inflation, we followed U.S. Environmental Protection Agency (EPA) guidelines (EPA, 2014). As in EPA guidelines, we used an income elasticity of the VSL of 0.40 and U.S. real GDP per capita as a measure of income to adjust for changes in income. We also used All-Items CPI to adjust for price changes (EPA, 2010; 2012).[5] More detailed documentation on how this is done is available on the USDA, ERS Cost of Foodborne Illness Data Product website (USDA, ERS Cost of Foodborne Illness Data Product, 2019).

## The Value of a Statistical Life Explained

To calculate the value of a statistical life (known as VSL), economists take the amount of money individuals are willing to pay for small changes in their risk of death and divide it by the change in risk. So, if the willingness to pay for a 1-in-10,000 reduction in risk of death is $600, the VSL is $6 million. The term "statistical life" refers to the fact that while each individual experiences a reduction in the *risk* of death, in aggregate a population of 10,000 people would experience one fewer death. This report uses an estimate for the VSL of $9.7 million (in 2018 U.S. dollars), based on a U.S. Environmental Protection Agency meta-analysis of existing estimates.

[4] Technically, estimates of willingness to pay to reduce the risk of death estimate an individual's "indirect utility function," v (p, w), where p is a vector of prices and w is income.

[5] As income rises, the demand for a good or service may change. An income elasticity of demand is the change in the quantity of the service or good demanded in response to a change in income. For many goods, like demand for reduction in risk of death, demand rises as income rises. An income elasticity of 0.40 implies that for each 1-percent increase in income, willingness to pay to reduce the risk of death increases by 0.40 percent.

# Results

We started our discussion of findings by presenting baseline estimates in 2013 of disease and economic burden for the 15 pathogens included in this study. We then looked at the nature of inflation and income growth in the U.S. economy from 2013 to 2018. We next looked at the impact of inflation and income growth on the total economic burden of foodborne illness from these major pathogens. We also looked at variation in changes in the burden and per capita burden by pathogen. We then examined how price inflation and income growth change the economic burden from medical care, productivity loss, and deaths. We end with a deeper dive into the role of inflation in specific types of medical care expenditures on our economic burden estimates.

## Baseline, 2013 Disease Estimates and Estimates of Total and Pathogen-Level Economic Burden

According to the 2011 CDC estimates of foodborne disease for the 15 pathogens included in the 2013 economic burden estimates, these pathogens caused 9.4 million illnesses, 56,000 hospitalizations, and slightly more than 1,400 deaths (table 2). Pathogen case estimates ranged from 96 for *Vibrio vulnificus* (close to zero percent of total cases) to 5.5 million for norovirus (58 percent of total cases). Hospitalizations ranged from 11 for *Cyclospora cayetanensis* (close to zero percent of total hospitalizations) to 19,000 for *Salmonella* (35 percent of total hospitalizations). Deaths ranged from zero for *STEC* non-O157:H7 to 342 for *Toxoplasma gondii* (24 percent of total deaths).

Economic burden is based on health outcomes. Health outcomes differ across pathogens. For example, in the CDC's 2011 foodborne disease incidence estimates, annual deaths by pathogen ranged from none for *Cyclospora cayetanensis* and Shiga-toxin producing STEC non-O157:H7 to a high of 378 for non-typhoidal *Salmonella* (table 2). The mean annual number of hospitalizations varied from a low of 11 for *Cyclospora* to a high of 19,366 for *Salmonella* (Scallan et al., 2011a) (table 2).[6]

Cases, hospitalizations, and deaths in 2011 were driven by a relatively small number of pathogens. A single pathogen, norovirus, caused 58 percent of cases. Only four pathogens, *Campylobacter*, *C. perfringens,* norovirus, and *Toxoplasma gondii*, caused more than 5 percent of hospitalizations. Three pathogens caused 73 percent of deaths.

In 2013, the total economic burden from the 15 pathogens was $15.5 billion. Total medical costs were $2 billion (table 3). As is typical in this type of study, productivity loss was much lower ($678 million) than total medical costs, and the value of avoiding deaths was much higher ($12.8 billion). Medical costs accounted for 13 percent of the total economic burden, productivity loss 4.4 percent, and deaths 82.6 percent.

[6]More detailed modeling of health outcomes and health care usage behind the ERS 2013 economic burden of foodborne disease estimates can be found in Hoffmann et al. (2012) and Batz et al. (2012).

Table 2

**Incidence of domestically acquired foodborne illnesses in the U.S. with identified pathogen cause**

| | Mean numbers | | | Mean percentage of total* | | |
|---|---|---|---|---|---|---|
| | Cases | Hospitalizations | Deaths | Cases | Hospitalizations | Deaths |
| *Campylobacter* spp. | 845,024 | 8,463 | 76 | 9.0 | 15.1 | 5.4 |
| *Clostridium perfringens* | 965,958 | 438 | 26 | 10.3 | 0.8 | 1.8 |
| *Cryptosporidium* spp. | 57,616 | 210 | 4 | 0.6 | 0.4 | 0.3 |
| *Cyclospora cayetanensis* | 11,407 | 11 | 0 | 0.1 | 0.0 | 0.0 |
| *E. coli* (STEC) O157 | 63,153 | 2,138 | 20 | 0.7 | 3.8 | 1.4 |
| *E. coli* (STEC) non-O157 | 112,752 | 271 | 0 | 1.2 | 0.5 | 0.0 |
| *Listeria monocytogenes* | 1,591 | 1,455 | 306** | 0.0 | 2.6 | 21.6 |
| Norovirus | 5,461,731 | 14,663 | 149 | 58.2 | 26.2 | 10.5 |
| *Salmonella* spp., non-typhoidal | 1,027,561 | 19,336 | 378 | 10.9 | 34.6 | 26.7 |
| *Shigella* spp. | 131,254 | 1,456 | 10 | 1.4 | 2.6 | 0.7 |
| *Toxoplasma gondii* | 86,686 | 4,428 | 342** | 0.9 | 7.9 | 24.2 |
| *Vibrio* spp., non-cholera | 17,564 | 83 | 8 | 0.2 | 0.1 | 0.6 |
| *Vibrio parahaemolyticus* | 34,664 | 100 | 4 | 0.4 | 0.2 | 0.3 |
| *Vibrio vulnificus* | 96 | 93 | 36 | 0.0 | 0.2 | 2.5 |
| *Yersinia enterocolitica* | 97,656 | 533 | 29 | 1.0 | 1.0 | 2.0 |
| 16 other identified pathogen causes | 473,362 | 2,283 | 29 | 5.0 | 4.1 | 2.0 |
| **Total** | **9,388,075** | **55,961** | **1,417** | **100.0** | **100.0** | **100.0** |

Notes: * Percentages do not add to 100 percent due to rounding.** Note that Batz, M., S. Hoffmann, and J.G. Morris Jr. 2014.“Disease-Outcome Trees, EQ-5D Scores, and Estimated Annual Losses of Quality-Adjusted Life Years (QALYs) Due to 14 Foodborne Pathogens in the United States,” *Foodborne Pathogen and Disease* 11(5): 395–402 model the impact of foodborne illnesses on neonatal deaths and stillbirths. These deaths are not included in Scallan E, R.M. Hoekstra, F.J. Angulo, R.V.Tauxe, M.A. Widdowson, S.L.Roy, et al. 2011. “Foodborne illness acquired in the United States—major pathogens,” *Emerging Infectious Diseases* 17(1): 7. As a result, mean annual deaths for *Listeria* and *Toxoplasma* are higher in this table than in Scallan et al. (2011).

Source: Scallan E, R.M. Hoekstra, F.J. Angulo, R.V.Tauxe, M.A. Widdowson, S.L.Roy, et al. 2011. “Foodborne illness acquired in the United States—major pathogens,” *Emerging Infectious Diseases* 17(1): 7.

Table 3

**Economic burden of 15 leading foodborne illnesses acquired in the United States, by pathogen (2013 dollars)**

| | Medical costs | Productivity loss | Deaths | Total |
|---|---|---|---|---|
| *Campylobacter* spp. | 463,207,755 | 59,191,761 | 1,406,387,650 | 1,928,787,166 |
| *Clostridium perfringens* | 53,247,647 | 64,329,568 | 225,091,283 | 342,668,498 |
| *Cryptosporidium* spp. | 7,805,136 | 9,379,088 | 34,629,428 | 51,813,652 |
| *Cyclospora cayetanensis* | 842,184 | 1,459,239 | N/A | 2,301,423 |
| *E. coli* (STEC) O157 | 34,619,998 | 5,643,034 | 231,155,658 | 271,418,690 |
| *E. coli* (STEC) non-O157 | 14,277,961 | 7,285,748 | 5,800,852 | 27,364,560 |
| *Listeria monocytogenes* | 137,159,768 | 48,410,168 | 2,648,874,266 | 2,834,444,202 |
| Norovirus | 597,916,921 | 367,964,199 | 1,289,946,198 | 2,255,827,318 |
| *Salmonella* spp., non-typhoidal | 312,738,453 | 81,380,620 | 3,272,480,959 | 3,666,600,031 |
| *Shigella* spp. | 42,130,731 | 9,261,661 | 86,573,570 | 137,965,962 |
| *Toxoplasma gondii* | 328,441,145 | 11,264,285 | 2,964,279,048 | 3,303,984,478 |
| *Vibrio* spp., non-cholera | 2,177,769 | 1,390,727 | 69,258,856 | 72,827,353 |
| *Vibrio parahaemolyticus* | 3,376,139 | 2,676,745 | 34,629,428 | 40,682,312 |
| *Vibrio vulnificus* | 7,970,516 | 214,923 | 311,664,853 | 319,850,293 |
| *Yersinia enterocolitica* | 19,104,658 | 7,943,156 | 251,063,354 | 278,111,168 |
| **Total** | **2,025,016,779** | **677,794,923** | **12,831,835,403** | **15,534,647,105** |
| | **Medical costs** | **Productivity loss** | **Deaths** | **Total** |
| | **Percent of total economic burden by pathogen** | | | |
| *Campylobacter* spp. | 24.02 | 3.07 | 72.92 | 100 |
| *Clostridium perfringens* | 15.54 | 18.77 | 65.69 | 100 |
| *Cryptosporidium* spp. | 15.06 | 18.10 | 66.83 | 100 |
| *Cyclospora cayetanensis* | 36.59 | 63.41 | N/A | 100 |
| *E. coli* (STEC) O157 | 12.76 | 2.08 | 85.17 | 100 |
| *E. coli* (STEC) non-O157 | 52.18 | 26.62 | 21.20 | 100 |
| *Listeria monocytogenes* | 4.84 | 1.71 | 93.45 | 100 |
| Norovirus | 26.51 | 16.31 | 57.18 | 100 |
| *Salmonella* spp., non-typhoidal | 8.53 | 2.22 | 89.25 | 100 |
| *Shigella* spp. | 30.54 | 6.71 | 62.75 | 100 |
| *Toxoplasma gondii* | 9.94 | 0.34 | 89.72 | 100 |
| *Vibrio* spp., non-cholera | 2.99 | 1.91 | 95.10 | 100 |
| *Vibrio parahaemolyticus* | 8.30 | 6.58 | 85.12 | 100 |
| *Vibrio vulnificus* | 2.49 | 0.07 | 97.44 | 100 |
| *Yersinia enterocolitica* | 6.87 | 2.86 | 90.27 | 100 |

Note: Economic burden is estimated as cost of treatment + productivity loss of working adults + willingness to pay to prevent deaths.

Source: Hoffmann, S., B. Maculloch, and M. Batz. 2015*.* ERS Economic Burden of Major Foodborne Illnesses Acquired in the United States. Economic Information Bulletin Series (EIB 140), USDA, Economic Research Service.

Medical costs and productivity losses by pathogen do not exactly parallel cases or hospitalizations by pathogen.[7] For example, while *Cyclospora* has the lowest medical costs as well as the lowest number of hospitalizations, it does not have the lowest number of cases—*Vibrio vulnificus* does. Similarly, though *Salmonella* has the highest number of hospitalizations, norovirus ranks second in cases and has the highest total medical costs (table 2). *Toxoplasma,* which has the second-highest medical costs, ranked fourth in hospitalizations and eighth in the number of cases. In general, the correlation between medical costs and cases (0.75) and hospitalizations (0.82) was slightly higher than the correlations between productivity loss and cases (0.72) or hospitalizations (0.68). This demonstrates that variation in the severity of illness by pathogen matters in determining the economic burden and is more complex than merely looking at the number of hospitalized cases across pathogens.

In 2013, as a percent of pathogen burden, medical costs ranged from a low of 2.5 percent for *Vibrio vulnificus* to a high of 52.2 percent for STEC non-O157:H7 (table 2). For five pathogens, medical costs accounted for almost 24 to 52 percent of the pathogen burden. Productivity loss ranged from a low of 0.07 percent for *Vibrio vulnificus* to a high of 63.4 percent for *Cyclospora cayetanensis.* For 10 pathogens, productivity loss counted for less than 10 percent of pathogen economic burden, but for *Cyclospora*, it was 63 percent. Deaths accounted for a low of 21.2 percent of total pathogen burden for STEC non-O157:H7 to a high of 97.4 percent for *Vibrio vulnificus.* For eight pathogens, death accounted for more than 75 percent of the pathogen burden. For two, death accounted for less than 25 percent of the pathogen burden.

## Inflation 2013 to 2018

The rate of inflation from 2013 to 2018 varied substantially across the components of the economic burden of foodborne disease (table 1). Health care prices generally increased more than overall prices during this 5-year period. The price of inpatient hospital services rose by 25 percent, outpatient hospital services by 22.3 percent, prescription drugs by 19.3 percent, and medical care for chronic disease by 14 percent, though physician's office visits rose only by 7.4 percent, and the price of over-the-counter drugs dropped by 2.4 percent. In comparison, economy-wide price inflation was 7.8 percent. During this same period, real per capita GDP, our measure of income, rose 8.8 percent.

## Impact of Inflation on Broad Components of Economic Burden

Differences in health outcomes across pathogens will influence the way inflation and income growth affect total economic burden and economic burden by pathogen. To estimate the impact of inflation and income growth on total burden and burden by pathogen, we first estimated their impacts on each of the three major components of economic burden: medical costs, productivity losses, and the economic burden of deaths, first by pathogen and then in aggregate. We started with a reminder of the role these components played in our 2013 estimates (Scallan et al., 2011a; Hoffmann et al., 2012; Batz et al., 2012). We looked at this by pathogen, both in terms of total and percent of the total.

## Impact of Inflation on Total Economic Burden and Economic Burden by Pathogen

Between 2013 and 2018, inflation and income growth increased the mean annual economic burden of illness caused by 15 major foodborne pathogens in the United States from $15.5 billion to $17.6 billion (table 4). This is a 13-percent increase in the total economic burden. The value of preventing these foodborne illnesses increased a bit more than 5 percentage points more than the overall increase in the value of goods and services between 2013 and 2018 (table 5).

[7]In our models, the VSL does not vary by pathogen.

Table 4

**Economic burden of 15 major foodborne illnesses by pathogen, in 2013 and 2018 dollars (sorted by percent change in total burden)**

| | 2013 dollars (rank) | 2018 dollars (rank) | Change 2013 to 2018 | | Percent of total in 2018 dollars (rank) |
|---|---|---|---|---|---|
| | | | Dollars | Percent | Percent |
| *E. coli* (STEC) non-O157 | 27,364,560 (14) | 31,701,852 (14) | 4,337,292 | 15.85 | .18 (14) |
| *Shigella* spp. | 137,965,962 (10) | 159,202,402 (10) | 21,236,440 | 15.39 | .89 (10) |
| *E. coli* (STEC) O157 | 271,418,690 (9) | 311,036,907 (9) | 39,618,217 | 14.60 | 1.75 (9) |
| Norovirus | 2,255,827,318 (4) | 2,566,984,191 (4) | 311,156,873 | 13.79 | 14.52 (4) |
| *Toxoplasma gondii* | 3,303,984,478 (2) | 3,744,008,907 (2) | 440,024,429 | 13.32 | 21.27 (2) |
| *Campylobacter* spp. | 1,928,787,166 (5) | 2,181,485,783 (5) | 252,698,617 | 13.10 | 12.42 (5) |
| *Salmonella* spp., non-typhoidal | 3,666,600,031 (1) | 4,142,179,161 (1) | 475,579,129 | 12.97 | 23.60 (1) |
| *Cryptosporidium* spp. | 51,813,652 (12) | 58,394,152 (12) | 6,580,500 | 12.70 | .33 12) |
| *Yersinia enterocolitica* | 278,111,168 (8) | 313,297,920 (8) | 35,186,752 | 12.65 | 1.79 (8) |
| *Listeria monocytogenes* | 2,834,444,202 (3) | 3,189,686,110 (3) | 355,241,908 | 12.53 | 18.25 (3) |
| *Vibrio parahaemolyticus* | 40,682,312 (13) | 45,735,332 (13) | 5,053,020 | 12.42 | 0.26 (13) |
| *Vibrio vulnificus* | 319,850,293 (7) | 359,481,557 (7) | 39,631,264 | 12.39 | 2.06 (7) |
| *Vibrio* spp., non-cholerae | 72,827,353 (11) | 81,749,064 (11) | 8,921,712 | 12.25 | 0.47 (11) |
| *Clostridium perfringens* | 342,668,498 (6) | 384,277,856 (6) | 41,609,358 | 12.14 | 2.21 (6) |
| *Cyclospora cayetanensis* | 2,301,423 (15) | 2,571,518 (15) | 270,095 | 11.74 | 0.01 (15) |
| Mean (average) | 1,035,643,140 | 1,171,452,847 | 135,809,707 | 13.19 | N/A |
| Median (50th percentile) | 278,111,168 | 313,297,920 | 39,618,217 | 12.70 | N/A |
| **Total** | **15,534,647,106** | **17,571,792,712** | **2,037,145,606** | **13.11** | **100** |

Source: USDA, Economic Research Service Cost of Foodborne Illness Data Product.

Table 5

**Real percent change in economic burden from 2013 to 2018, by pathogen***

| | Real Percent change 2013 to 2018 |
|---|---|
| *E. coli* (STEC) non-O157 | 6.80% |
| *Shigella* spp. | 8.05% |
| *E. coli* (STEC) O157 | 7.59% |
| Norovirus | 5.99% |
| *Toxoplasma gondii* | 5.52% |
| *Campylobacter* spp. | 5.30% |
| *Salmonella* spp., non-typhoidal | 5.17% |
| *Cryptosporidium* spp. | 4.90% |
| *Yersinia enterocolitica* | 4.85% |
| *Listeria monocytogenes* | 4.73% |
| *Vibrio parahaemolyticus* | 4.62% |
| *Vibrio vulnificus* | 4.59% |
| *Vibrio* spp., non-cholera | 4.45% |
| *Clostridium perfringens* | 4.34% |
| *Cyclospora cayetanensis* | 3.94% |
| **All 15 major pathogens** | **5.31%** |

*Real percent change in economic burden is defined as the difference between the nominal change from 2013 to 2018 less the percent change in the all items CPI.

Source: USDA, Economic Research Service Cost of Foodborne Illness Data Product.

Pathogen-level changes in total economic burden from foodborne illness ranged from a low of $270,000 for *Cyclospora cayetanensis* to a high of $475.6 million for *Salmonella* (table 4). The percent change in burden ranged from 11.7 percent for *Cyclospora* to 15.8 percent for *STEC* non-O157:H7. Even though the percent changes in pathogen burden was fairly evenly distributed around the mean of 13.2 percent, the absolute change in burden was not. Like the burden estimates themselves, many pathogens had fairly small changes in burden, while a few had very large changes. (The 50th percentile, or median, change was $40 million, and the mean change was $136 million) (table 4). This shows that while inflation and income growth affect pathogens fairly similarly on a percentage basis, the initial pathogen burden level was determining the size of the absolute change. Further analysis of how inflation and income growth affect components of the economic burden by pathogen is needed to understand what drives the percentage change and whether this differs by pathogen. Economic burden estimates also inform thinking about which pathogens to prioritize in control efforts. Our analysis showed the rank of pathogens by burden did not change after adjusting for inflation and income growth (table 4).

A pathogen's change in response to inflation and income growth relative to others might suggest where the value of prevention is rising at the fastest rate. The percent change in economic burden ranged from 16 percent for STEC non-O157 to 12 percent for *Cyclospora*. The pathogens' rankings by percent change and by economic burden were not the same. The rate of change in burden was not simply a matter of the size of the pathogen's economic burden in 2013 (table 4). For example, STEC non-O157:H7 ranked 14th in burden and 1st in percent change; *Salmonella*, which ranked 1st in terms of burden, ranked 9th in terms of percent change. *Cyclospora* ranked 15th in both burden and percent change in burden. Quantitatively, the correlation between the rank of pathogens by the percent change in economic burden and the rank of pathogens by economic burden was low (rank correlation of 0.15 on a scale of zero (no correlation) to 1 (fully correlated)).

Table 6
**Per-case economic burden of 15 major foodborne illnesses by pathogen, in 2013 and 2018 dollars**

| | Per-case economic burden in dollars 2013 | Per-case economic burden in dollars 2018 | Change from 2013 to 2018 | Percent change from 2013 to 2018 | Rank, per-case burden 2013 and 2018 | Rank, change in per-case burden 2013 to 2018 |
|---|---|---|---|---|---|---|
| *E. coli* (STEC) non-O157 | 243 | 281 | 38 | 15.9 | 14 | 14 |
| *Shigella* spp. | 1,051 | 1,213 | 162 | 15.4 | 10 | 9 |
| *E. coli* (STEC) O157 | 4,298 | 4,925 | 627 | 14.6 | 4 | 4 |
| Norovirus | 413 | 470 | 57 | 13.8 | 12 | 12 |
| *Toxoplasma gondii* | 38,114 | 43,190 | 5,076 | 13.3 | 3 | 3 |
| *Campylobacter* spp. | 2,283 | 2,582 | 299 | 13.1 | 8 | 8 |
| *Salmonella* spp., non-typhoidal | 3,568 | 4,031 | 463 | 13.0 | 6 | 6 |
| *Cryptosporidium* spp. | 899 | 1,014 | 114 | 12.7 | 11 | 11 |
| *Yersinia enterocolitica* | 2,848 | 3,208 | 360 | 12.7 | 7 | 7 |
| *Listeria monocytogenes* | 1,781,549 | 2,004,831 | 223,282 | 12.5 | 2 | 2 |
| *Vibrio parahaemolyticus* | 1,174 | 1,319 | 146 | 12.4 | 9 | 10 |
| *Vibrio vulnificus* | 3,331,774 | 3,744,600 | 412,826 | 12.4 | 1 | 1 |
| *Vibrio* other spp., non-cholerae | 4,146 | 4,654 | 508 | 12.3 | 5 | 5 |
| *Clostridium perfringens* | 355 | 398 | 43 | 12.1 | 13 | 13 |
| *Cyclospora cayetanensis* | 202 | 225 | 24 | 11.7 | 15 | 15 |
| Median | 2,283 | 2,582 | 299 | 12.70 | | |
| Mean | 344,861 | 387,796 | 42,935 | 13.19 | | |

Source: USDA, Economic Research Service Cost of Foodborne Illness Data Product.

## Changes in Per-Case Economic Burden by Pathogen

Policymakers, managers, or consumers might also be concerned about preventing illnesses that have particularly bad outcomes for individuals. This is measured by per-case economic burden. Mean per-case economic burden increased from $345,000 in 2013 to $388,000 in 2018 (table 6). As with total economic burden, the distribution of change in per-case economic burden across pathogens was highly skewed, i.e., most pathogens had fairly low per-case burden, and two (Listeria and *Vibrio vulnificus*) had much higher burdens. Changes in per-case pathogen burden from 2013 to 2018 ranged from a low of $24 for *Cyclospora cayetanensis* to a high of $413,000 for *Vibrio vulnificus*. There was not much difference in the rank of pathogens by per-case economic burden and rank by change in per-case burden from 2013 to 2018 (rank correlation of 0.99). Again, as with total economic burden, the rank by burden did not drive the ranking of pathogens by percent change in per-case burden (rank correlation of -0.025). So if the concern is which pathogen has the largest percent change in per-case burden, it is not enough just to look at the pathogens with the largest or smallest burden. Something other than total burden is driving the percent change in per-case burden as well. That factor must be change in one of the three major components of economic burden.

## Impact of Inflation and Income Growth by Component of Total Economic Burden

To explore the question of what drives differences in the way inflation and income growth affect economic burden at the pathogen level, we started by looking at the change in economic burden by broad components of the economic burden of illness. We first looked at total change by components of all pathogens. The economic burden of medical costs increased from $2 billion in 2013 to $2.5 billion in 2018 (tables 2 and 7).

Productivity loss associated with foodborne illness increased from $678 million in 2013 to $731 million in 2018. Additionally, the economic burden of deaths from 15 leading foodborne pathogens increased from $12.8 billion in 2013 to $14.4 billion in 2018 (tables 2 and 7).

Table 7

**Economic burden from medical costs, productivity loss and deaths, 2018 dollars, and change from 2013 dollars**

| | Medical costs | | Productivity loss | | Deaths | |
|---|---|---|---|---|---|---|
| | Economic burden 2018 dollars | Change in burden 2013 to 2018 | Economic burden 2018 dollars | Change in burden 2013 to 2018 | Economic burden 2018 dollars | Change in burden 2013 to 2018 |
| *Campylobacter* spp. | 541,492,327 | 78,284,573 | 63,803,408 | 4,611,646 | 1,576,190,048 | 169,802,398 |
| *Clostridium perfringens* | 62,668,324 | 9,420,678 | 69,341,503 | 5,011,934 | 252,268,029 | 27,176,746 |
| *Cryptosporidium* spp. | 9,473,871 | 1,668,735 | 10,109,815 | 730,727 | 38,810,466 | 4,181,038 |
| *Cyclospora cayetanensis* | 998,589 | 156,405 | 1,572,929 | 113,690 | N/A | N/A |
| *E. coli* (STEC) O157 | 41,740,054 | 7,120,056 | 6,082,684 | 439,650 | 263,214,169 | 32,058,511 |
| *E. coli* (STEC) non-O157 | 16,932,286 | 2,654,325 | 7,853,382 | 567,634 | 6,916,184 | 1,115,332 |
| *Listeria monocytogenes* | 168,678,679 | 31,518,911 | 52,181,817 | 3,771,649 | 2,968,825,614 | 319,951,348 |
| Norovirus | 724,661,944 | 126,745,023 | 396,632,390 | 28,668,191 | 1,445,689,857 | 155,743,659 |
| *Salmonella* spp., non-typhoidal | 386,869,122 | 74,130,669 | 87,721,006 | 6,340,386 | 3,667,589,032 | 395,108,074 |
| *Shigella* spp. | 52,192,997 | 10,062,266 | 9,983,240 | 721,579 | 97,026,165 | 10,452,595 |
| *Toxoplasma gondii* | 409,691,133 | 81,249,988 | 12,141,888 | 877,604 | 3,322,175,885 | 357,896,837 |
| *Vibrio* spp., non-cholera | 2,629,053 | 451,284 | 1,499,079 | 108,352 | 77,620,932 | 8,362,076 |
| *Vibrio parahaemolyticus* | 4,039,575 | 663,436 | 2,885,291 | 208,546 | 38,810,466 | 4,181,038 |
| *Vibrio vulnificus* | 9,955,695 | 1,985,179 | 231,668 | 16,745 | 349,294,194 | 37,629,340 |
| *Yersinia enterocolitica* | 23,360,033 | 4,255,375 | 8,562,009 | 618,853 | 281,375,878 | 30,312,524 |
| All 15 Pathogens | 2,455,383,683 | 430,366,904 | 730,602,110 | 52,807,187 | 14,385,806,919 | 1,553,971,515 |

Source: USDA, Economic Research Service calculations.

A small number of pathogens drove costs in each major component of the economic burden (table 7). *Campylobacter* and norovirus accounted for 52 percent of medical costs in 2018. Norovirus alone accounted for 54 percent of 2018 productivity loss due to the large number of cases it caused, even though the illnesses are generally mild and of relatively short duration (table 7). *Salmonella* and *Toxoplasma* accounted for 49 percent of the 2018 economic burden due to deaths. Five pathogens caused 90 percent or more of the 2018 total economic burden for each burden component.

The impacts of inflation on medical costs were much larger in percentage terms than its impacts on productivity loss or the impact of inflation and income growth on the economic burden of deaths (table 8). Total medical costs for the 15 foodborne pathogens in USDA, ERS estimates increased by 21.3 percent from 2013 to 2018 or by 13.5 percent more than overall price inflation (table 8). Because productivity loss is adjusted using the All-Items CPI, it rose at that same rate as overall prices economy-wide or 7.8 percent. The value of the economic burden of death rose by 12 percent or 4.2 percent more than overall price inflation.

Table 8

**Percent change in major component burden from 2013 to 2018, by pathogen**

| | Relevant pathogens | Percent change 2013 to 2018 | Real percent change 2013 to 2018 |
|---|---|---|---|
| Medical cost | *Campylobacter* spp. | 16.9 | 9.1 |
| | *Clostridium perfringens* | 17.7 | 9.9 |
| | *Cryptosporidium* spp. | 21.4 | 13.6 |
| | *Cyclospora cayetanensis* | 18.6 | 10.8 |
| | *E. coli* (STEC) O157 | 20.6 | 12.8 |
| | *E. coli* (STEC) non-O157 | 18.6 | 10.8 |
| | *Listeria monocytogenes* | 23.0 | 15.2 |
| | Norovirus | 21.2 | 13.4 |
| | *Salmonella* spp., non-typhoidal | 23.7 | 15.9 |
| | *Shigella* spp. | 23.9 | 16.1 |
| | *Toxoplasma gondii* | 24.7 | 16.9 |
| | *Vibrio* spp., non-cholera | 20.7 | 12.9 |
| | *Vibrio parahaemolyticus* | 19.7 | 11.9 |
| | *Vibrio vulnificus* | 24.9 | 17.1 |
| | *Yersinia enterocolitica* | 22.3 | 14.5 |
| | All 15 pathogens | 21.3 | 13.5 |
| Productivity loss | | 7.8 | 0.0 |
| Death | | 12.1 | 4.3 |
| **Total** | | **13.1** | **5.3** |

Note: The rate of increase in productivity loss and in the economic burden was the same for each pathogen because each involves only one inflation adjustment. Medical costs are a composite of the cost of physician office visits, prescription drugs, over-the-counter drugs, emergency room care, and inpatient hospital care—the price of each of which is changing at different rates and is used in different proportions to treat different pathogens.

Source: USDA, Economic Research Service calculations.

The change in medical costs varied across pathogens because pathogens have different incidence and severity and therefore require different utilization of medical goods and services. Increases in medical costs varied from 16.9 percent for *Campylobacter* to 24.9 percent for *Vibrio vulnificus* (table 8).

Despite this sizable difference in the percent change in major components of economic burden, the contribution of each of the 3 components to the total economic burden from the 15 pathogens did not change very much from 2013 to 2018. Across all 15 pathogens, medical costs accounted for 14 percent of the total economic burden in 2018, compared to 13 percent in 2013. Productivity losses accounted for 4.4 percent of the total economic burden in 2018 compared to 4.2 percent in 2013. The percent due to willingness to pay to reduce the risk of death declined by 0.7 percentage points. Even with this decline, deaths continued to account for nearly 82 percent of the economic burden of foodborne disease.

## Impact of Inflation on Per-Case Economic Burden by Major Component of Burden

On a per-case basis, a small number of pathogens stand out as having particularly high medical costs (table 9). *Listeria*, *Vibrio vulnificus*, and *E. coli* (STEC) 0157 have per-case medical costs ranging from $4,700 to $107,000 in 2018 dollars. The remaining pathogens have relatively low per-case medical costs, resulting in the median of $239 being far below the mean of $14,509. *Listeria* and *Vibrio* also had high per-case productivity loss in 2018 dollars, $33,000 and $2,400, respectively. The remaining pathogens had low levels of per-case productivity loss with a median of $85 and a mean of $2,400 in 2018 dollars. It is worth noting that the ranking of pathogens by per-case medical costs and the ranking by per-case labor productivity loss did not track one another. Overall, the change in medical costs was substantially higher than the change in productivity loss, a mean of $2,798 compared to a mean of $176.

Table 9
**Per-case medical cost and productivity loss, by pathogen, 2018 dollars**

| | Per-case medical costs | Change per-case medical costs 2013 dollars to 2018 dollars | Per-case productivity loss | Change per-case productivity loss 2013 dollars to 2018 dollars | Cases |
|---|---|---|---|---|---|
| *Campylobacter* spp. | 641 | 93 | 76 | 5 | 845,024 |
| *Clostridium perfringens* | 65 | 10 | 72 | 5 | 965,958 |
| *Cryptosporidium* spp. | 164 | 29 | 175 | 13 | 57,616 |
| *Cyclospora cayetanensis* | 88 | 14 | 138 | 10 | 11,407 |
| *E. coli* (STEC) O157 | 661 | 113 | 96 | 7 | 63,153 |
| *E. coli* (STEC) non-O157 | 150 | 24 | 70 | 5 | 112,752 |
| *Listeria monocytogenes* | 106,021 | 19,811 | 32,798 | 2,371 | 1,591 |
| Norovirus | 133 | 23 | 73 | 5 | 5,461,731 |
| *Salmonella* spp., non-typhoidal | 376 | 72 | 85 | 6 | 1,027,561 |
| *Shigella* spp. | 398 | 77 | 76 | 5 | 131,254 |
| *Toxoplasma gondii* | 4,726 | 937 | 140 | 10 | 86,686 |
| *Vibrio* spp., non-cholera | 150 | 26 | 85 | 6 | 17,564 |
| *Vibrio parahaemolyticus* | 117 | 19 | 83 | 6 | 34,664 |
| *Vibrio vulnificus* | 103,705 | 20,679 | 2,413 | 174 | 96 |
| *Yersinia enterocolitica* | 239 | 43 | 88 | 6 | 97,656 |
| Mean | 14,509 | 2,798 | 2,431 | 176 | |

Source: USDA, Economic Research Service calculations.

## Drivers of Variation in Changes in Medical Costs Across Pathogens

What drove increases in medical costs? Inflation was not uniform across all areas of health care services and goods, ranging from 25 percent-inflation in inpatient hospital services over the 5-year period from 2013 to 2018 to 2.4-percent deflation in over-the-counter drugs (table 1). Different pathogens had different incidence and hospitalization rates (table 2). Variability in the severity of illness across pathogens also resulted in the use of different types of health care services and goods to treat the illnesses caused by different pathogens, and this also created variability in costs (table 10). For example, hospital care accounted for only 19.6 percent of medical treatment costs for illnesses caused by *Clostridium* in 2013, but it accounted for 99.5 percent of the cost of treating *Vibrio vulnificus* infections (table 10). Among the four pathogens with the largest economic burden—*Listeria*, norovirus, *Salmonella*, and *Toxoplasma*—more than 85 percent of their medical costs were due to inpatient hospital care (table 10).

Table 10

**Percentage share of total medical cost for foodborne disease, by specific medical services and pathogen, 2013 dollars**

| Pathogen | Medications | Physician office visits | Emergency room visits | Outpatient clinic visits | Hospitalizations | Chronic medical costs | Total Medical Cost |
|---|---|---|---|---|---|---|---|
| *Campylobacter* spp. | 0.00 | 2.30 | 0.88 | 2.19 | 25.47 | 69.17 | 100 |
| *Clostridium perfringens* | 0.00 | 34.37 | 10.43 | 35.60 | 19.60 | 0.00 | 100 |
| *Cryptosporidium* spp. | 0.00 | 16.91 | 5.37 | 17.28 | 60.44 | 0.00 | 100 |
| *Cyclospora cayetanensis* | 0.00 | 30.21 | 9.23 | 31.23 | 29.34 | 0.00 | 100 |
| *E. coli* (STEC) O157 | 1.31 | 6.83 | 11.09 | 0.00 | 55.01 | 25.76 | 100 |
| *E. coli* (STEC) non-O157 | 4.52 | 25.64 | 34.66 | 0.00 | 28.94 | 6.25 | 100 |
| *Listeria monocytogenes* | 0.00 | 0.00 | 0.00 | 0.00 | 88.50 | 11.50 | 100 |
| Norovirus | 0.00 | 17.78 | 5.60 | 18.20 | 58.42 | 0.00 | 100 |
| *Salmonella* spp., non-typhoidal | 0.00 | 5.92 | 2.42 | 5.49 | 86.18 | 0.00 | 100 |
| *Shigella* spp. | 0.00 | 5.07 | 1.88 | 4.89 | 88.17 | 0.00 | 100 |
| *Toxoplasma gondii* | 0.00 | 1.02 | 0.45 | 0.92 | 97.61 | 0.00 | 100 |
| *Vibrio* spp., non-cholera | 0.00 | 20.02 | 6.43 | 20.43 | 53.12 | 0.00 | 100 |
| *Vibrio parahaemolyticus* | 0.00 | 25.10 | 7.86 | 25.76 | 41.28 | 0.00 | 100 |
| *Vibrio vulnificus* | 0.00 | 0.22 | 0.18 | 0.15 | 99.46 | 0.00 | 100 |
| *Yersinia enterocolitica* | 0.00 | 12.69 | 4.07 | 12.86 | 70.38 | 0.00 | 100 |

Source: USDA, Economic Research Service calculations.

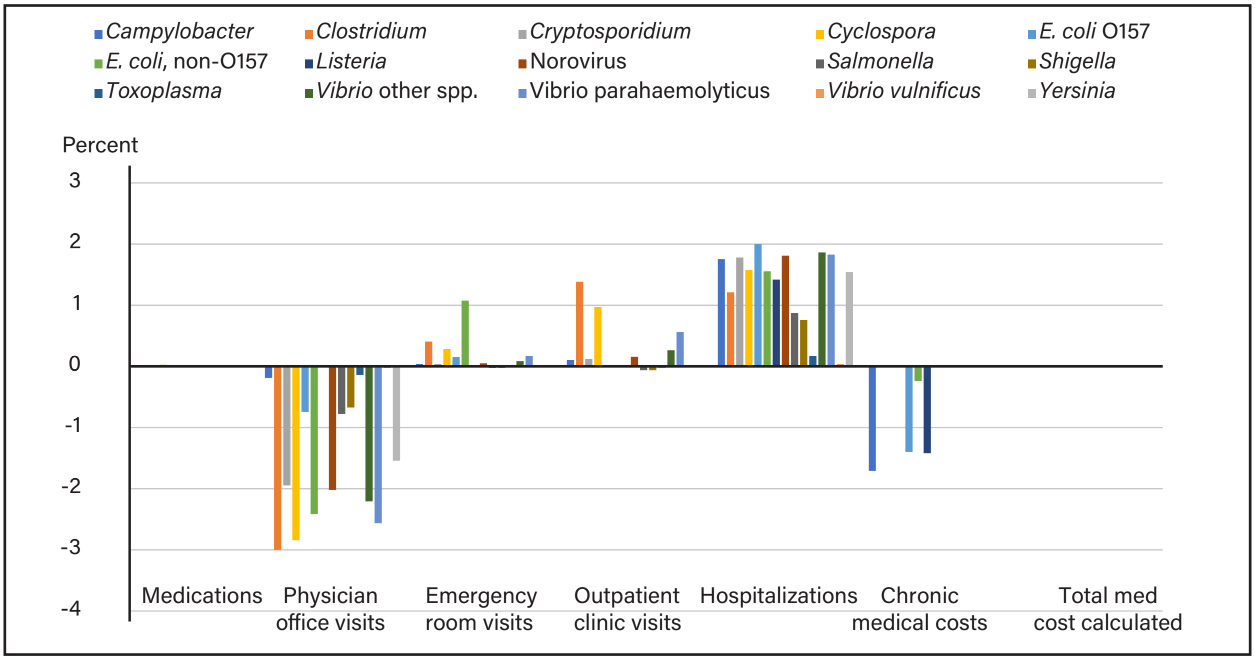
Looking across pathogens, it is clear that hospitalization costs drove total medical costs, with a correlation of 0.89 (table 10). But there were pathogens for which other medical costs were more important than hospital costs. For four pathogens—*Campylobacter*, *Clostridium perfringens*, *Cyclospora cayetanensis*, and *STEC* O157:H7—the share of medical cost due to hospitalization was exceeded by the share due to chronic illness, outpatient clinic, physician office, or emergency visits (table 10).[8]

Across all pathogens, the share of medical cost due to hospitalization rose, and the share due to physician office visits fell when the economic burden of foodborne disease estimates were updated for inflation and income growth (figure 2). Hospitalization costs also emerged as the major driver of total medical cost inflation. Changes in hospitalization costs from 2013 to 2018 accounted for 74 percent of the change in total medical costs (table 11).

[8]Chronic medical costs for Campylobacter spp. were adjusted for inflation in the same ways as hospitalization costs.

Figure 2

**Percent change in costs by pathogen, 2013 to 2018**




Source: U.S. Centers for Disease Control and Prevention.

Table 11

**Change from 2013 to 2018 as a percent of change in medical costs or as a percent change in total economic burden**

| Change 2013 to 2018 as a percent of change in: | Medications | Physician office visits | Emergency room visits | Outpatient clinic visits | Hospitalizations | Chronic medical costs | Productivity loss | Deaths |
|---|---|---|---|---|---|---|---|---|
| | Percent change | | | | | | | |
| Total medical cost | 0.05 | 2.94 | 3.28 | 8.57 | 74.12 | 11.04 | N/A | N/A |
| Total economic burden | 0.01 | 0.62 | 0.69 | 1.81 | 15.67 | 2.33 | 2.59 | 76.26 |

Source: USDA, Economic Research Service calculations.

## The Impact of Inflation on Medical Costs Compared to Deaths

Despite the major role that increases in hospitalization costs play in driving increases in total medical cost, deaths remain the major driver of total economic burden. In 2013, deaths accounted for 83 percent, and medical costs accounted for 13 percent of the total economic burden from disease caused by the 15 foodborne pathogens included in USDA, ERS's cost-of-illness estimates. Even though the economic burden of deaths rose by only 12 percent between 2013 and 2018 while inpatient hospitalization costs rose by 25 percent, the change in the economic burden of deaths caused 76 percent of the change in total economic burden from all 15 pathogens in USDA, ERS's cost-of-illness estimates. This is because deaths accounted for 83 percent of the total economic burden from the 15 pathogens in 2013. This does not mean that inflation in hospitalization costs did not affect the change in the total economic burden of disease.

Because of the high inflation rate seen in hospitalization costs, that change accounted for 16 percent of the change in the total economic burden between 2013 and 2018 (table 11). This was true even though hospitalization costs accounted for only 12 percent of the total economic burden across all 15 pathogens in 2013. The bottom line is that the 25 percent-inflation in inpatient hospital care costs between 2013 and 2018 had a noticeable impact on the total economic burden of these foodborne diseases. Medical costs, particularly inpatient hospital care costs, had a much higher inflation rate than the economic burden of deaths; but because deaths caused such a large proportion of economic burden in 2013, the change in the economic burden of deaths was a much larger percentage of the change in total economic burden from 2013 to 2018 than hospitalization costs or total medical costs.

## Conclusions and Limitations

This study updates USDA, ERS estimates of the economic burden of 15 major foodborne diseases for inflation and income growth from 2013 to 2018. These pathogens accounted for more than 95 percent of cases, hospitalizations, and deaths from the 31 pathogens for which the CDC has estimated pathogen-specific incidence of foodborne disease (Hoffmann et al., 2015). This study does not update disease incidence, health care utilization estimates, or disease outcome modeling.

Inflation differed across the different components of the economic burden of illness, including wages, doctor's office visits, prescription drugs, over-the-counter drugs, emergency room care, special education for disabled children, and inpatient hospital services. Inflation ranged from a 2.4-percent nominal decrease in the price of over-the-counter drugs to a 25-percent increase for inpatient hospital care costs from 2013 to 2018 (table 1). During the same period, overall prices increased by 7.8 percent, and real per-capita GDP increased by 8.8 percent. This paints a picture of an economy in which overall price inflation was slightly less than the increase of resources available in the economy to buy goods and services. It also paints a picture of an economy in which medical care prices were generally rising much faster than overall price inflation.

A major message from this analysis is that even in a period of relatively low overall inflation and income growth, inflation and income growth can affect the economic burden of disease estimates. The total economic burden of these major foodborne diseases increased by 13 percent from $15.5 billion in 2013 dollars to $17.6 billion in 2018 dollars (table 4). This means the value of preventing these foodborne illnesses increased by about 5 percent more than overall price inflation during this 5-year period. Preventing foodborne diseases became more valuable relative to other goods and services.

There has been substantial attention given to inflation in health care costs in recent years, and we see this is part of what is driving an increase in the economic impact of foodborne disease associated with inflation and income growth. Inflation in medical care prices caused the economic burden from these pathogens to increase by about 21 percent, from $2 billion in 2013 dollars to $2.4 billion in 2018 dollars. Seventy-four percent of this increase in medical costs was due to a 25-percent inflation in the price of inpatient hospital services.

Finally, even though there was only a 12-percent increase in the value people place on preventing death, the economic burden of deaths overshadowed hospital costs as the primary factor driving total increase in the economic burden of these foodborne diseases. This is because of the high value people place on the protection of life. In 2013, deaths accounted for 83 percent of the total economic burden from these pathogens. The economic burden of death from these pathogens increased by 12 percent, from $12.8 billion in 2013 dollars to $14.4 billion in 2018 dollars. As a result, the increase in economic burden from deaths accounted for 76 percent of the total increase in the economic burden from these pathogens while the increase in medical costs accounted for 21 percent.

Values also changed at the pathogens level. Based on 2013 price levels, the economic burden of individual pathogens ranged from a low of $2.3 million for *Cyclospora* to a high of $3.7 million for *Salmonella.* Using 2018 price levels, the economic burden by pathogen ranged from $2.6 million for *Cyclospora cayetanensis* to $4.1 million for *Salmonella.* Despite increases in the economic burden posed by specific pathogens, the ranking of pathogens by economic burden did not change from 2013 to 2018. This matters for those using these estimates to inform priority setting across pathogens.

We do not update disease incidence estimates underlying the USDA, ERS estimates of the economic burden of foodborne illness. The CDC has the responsibility for updating the incidence of foodborne disease in the United States. This is a complex modeling effort that has been done roughly every 10 years since the late 1990s. While FoodNet—which collects active surveillance data of foodborne diseases in 10 States—can be used to get a sense of trends in foodborne illness incidence, by itself, it cannot be looked to as new estimates of foodborne disease incidence. Similarly, data on cases of illness from foodborne disease outbreaks cannot be considered new estimates of foodborne disease incidence. Outbreak cases constitute a relatively small percentage of overall foodborne illness and are not representative of the patterns of overall foodborne disease. USDA, ERS will update its cost economic burden of foodborne disease estimates in response to new CDC foodborne disease incidence estimates.

We also did not update for changes in health care utilization. The authors, together with colleagues at academic institutions, are currently in the midst of a multi-year research project involving a major revision of the disease outcome and health care utilization modeling that underlies these economic burden estimates. As part of this effort, we are also conducting research to provide a more complete accounting for the chronic impacts of foodborne disease, including chronic kidney disease, cognitive impairment following listerial meningitis, and blindness in newborns following toxoplasmosis.

A limitation of the methods used by USDA, ERS to estimate the economic burden of nonfatal illnesses is that they do not capture the value people place on avoiding the pain and suffering caused by illness. This is a long-standing methodological challenge of broad concern among public health economists. The Organization of Economic Cooperation and Development (OECD) is leading a research effort by member states, including the United States, to develop estimates of willingness to pay to reduce the risk of nonfatal illness from chemical exposures, including chronic kidney disease (OECD, 2020). STEC O157 produces a biotoxin that can damage kidneys. The United Kingdom Food Safety Authority (UKFSA) and researchers at the University of Manchester recently developed stated-preference surveys to estimate willingness to pay to reduce the risk of nonfatal foodborne illness (UKFSA, 2020). USDA, ERS has just funded a similar valuation study of nonfatal foodborne disease in the United States. Researchers funded by Food Standards Australia New Zealand (FSANZ) are doing similar research in Australia (FSANZ, 2020). These updated estimates together with future research will help ensure the public and policy makers have up-to-date information on the costs of foodborne illnesses for use in policy decisions.

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