



HHS Public Access

Author manuscript

Vaccine. Author manuscript; available in PMC 2018 March 01.

Published in final edited form as:

Vaccine. 2017 October 13; 35(43): 5905–5911. doi:10.1016/j.vaccine.2017.08.075.

Cost of a measles outbreak in a remote island economy: 2014 Federated States of Micronesia measles outbreak

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Abstract

After 20 years with no reported measles cases, on May 15, 2014 the Centers for Disease Control and Prevention (CDC) was notified of two cases testing positive for measles-specific immunoglobulin M (IgM) antibodies in the Federated States of Micronesia (FSM). Under the Compact of Free Association, FSM receives immunization funding and technical support from the United States (US) domestic vaccination program managed by the Centers for Disease Control and Prevention (CDC). In a collaborative effort, public health officials and volunteers from FSM and the US government worked to respond and contain the measles outbreak through an emergency mass vaccination campaign, contact tracing, and other outbreak investigation activities. Contributions were also made by United Nations Children's Emergency Fund (UNICEF) and World Health Organization (WHO). Total costs incurred as a result of the outbreak were nearly \$4,000,000; approximately \$10,000 per case. Direct medical costs (~\$141,000) were incurred in the treatment of those individuals infected, as well as lost productivity of the infected and informal caregivers (~\$250,000) and costs to contain the outbreak (~\$3.5 million). We assessed the economic burden of the 2014 measles outbreak to FSM, as well as the economic responsibilities of the US. Although the US paid the majority of total costs of the outbreak (~67%), examining each country's costs relative to their respective economy illustrates a far greater burden to FSM. We demonstrate that while FSM was heavily assisted by the US in responding to the 2014 Measles Outbreak, the outbreak significantly impacted their economy. FSM's economic burden from the outbreak is approximately equivalent to their entire 2016 Fiscal Year budget dedicated to education.

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Conflict of interest

All authors have read and approved the manuscript, and there are no financial disclosures, conflicts of interests and/or acknowledgements necessary.

The findings and conclusions in this report are those of the authors and do not necessarily represent the official position of the Centers for Disease Control and Prevention.

Appendix A. Supplementary material

Supplementary data associated with this article can be found, in the online version, at <http://dx.doi.org/10.1016/j.vaccine.2017.08.075>.

Keywords

Cost of outbreak; Economic burden; Federated States of Micronesia; Measles

1. Introduction

Measles is a highly contagious rash illness that is transmitted from person to person by direct contact with respiratory droplets or airborne spread [1]. Once a common disease, tremendous progress has been made to reduce measles burden across the world, and cases have dramatically decreased with proliferation of two dose measles-containing vaccine coverage use [2]. According to the World Health Organization (WHO), from 2000 to 2014, measles mortality decreased by 79% from an estimated 546,800 in 2000 to 114,900 in 2014, and vaccination prevented an estimated 17.1 million deaths [3]. As a result, the WHO Global Vaccine Action Plan for 2012–2020 aims to eliminate measles in at least five WHO Regions by 2020 [2]. Despite the availability of a safe and effective vaccine, measles remains one of the leading causes of death among young children [3].

As a member country of the WHO Western Pacific Region, the Federated States of Micronesia (FSM) is committed to eliminating measles through achieving and maintaining regional goals of 95% vaccination coverage with 2 doses of measles-containing vaccine (MCV) for each birth cohort of children (WHO website).¹ Under the Compact of Free Association, FSM receives immunization funding and technical support from the United States (US) domestic vaccination program managed by the Centers for Disease Control and Prevention (CDC). The international agreement establishes and governs the relationships of free association between the US and the three Pacific Island nations that formerly comprised the Trust Territory of the Pacific Islands: the Federated States of Micronesia, the Marshall Islands, and Palau [4]. Measles vaccination policy has evolved in FSM from one dose of monovalent measles vaccine at 9 months of age in 1963, to the current recommendation of two doses of measles, mumps, and rubella (MMR) vaccine, administered at 12 and 13 months [5,6]. Two doses of MMR are required for school entry [5,6], although enforcement is not stringent.

After 20 years with no reported measles cases, on May 15, 2014, CDC was notified of two cases testing positive for measles-specific immunoglobulin M (IgM) antibodies in FSM. Subsequently, 393 cases of measles were confirmed in FSM; 140 (36%) were laboratory confirmed, 244 (62%) were epidemiologically confirmed, and nine (2%) were clinically compatible [5,7].

In a collaborative effort, FSM public health officials, volunteers supplied by FSM, and staff from CDC worked to respond and contain the measles outbreak through an emergency mass vaccination campaign, contact tracing, and other outbreak investigation activities. Contributions were also made by United Nations Children’s Emergency Fund (UNICEF) and WHO. Direct medical costs were incurred in the treatment of those individuals infected,

¹A single dose of MCV was introduced in FSM in 1963 and was replaced in 1982 with the MMR vaccine. A second dose of MMR was introduced was introduced in 1995.

as well as costs from lost productivity of the infected and time of the care-givers, and costs to contain the outbreak.

During a measles outbreak, the resources needed to identify and treat contacts can strain local public health resources [8]. In the case of FSM, a lower middle income country with a narrowly-based economy, this strain on resources was exacerbated by the unique logistical, economic, and geographical challenges in confirming diagnosis and containing the outbreak in a vast archipelago of islands with small and dispersed human populations. Although many aspects of this study are relevant to other countries, the idiosyncrasies of this event coupled with the Compact of Free Association with the US provide an opportunity to determine the economic implications of such an event to all parties. The objective of this report is to assess the economic burden of the 2014 measles outbreak to FSM in terms of containment costs, direct medical costs, and productivity losses, as well as the economic responsibilities of the US. Although the US paid the majority of total costs of the outbreak, examining each country's costs relative to their respective economy illustrates a far greater burden to FSM.

2. Methods

2.1. Setting

FSM is an independent nation comprising 607 islands located just north of the Equator in the Western Pacific Ocean. The islands are dispersed across 1 million square miles (2.6 million square kilometers) of ocean. FSM is made up of four groups of island states in geographic sequence from west to east: Yap, Chuuk, Pohnpei and Kosrae. According to the 2010 census, the population of 102,843 is distributed as follows: Chuuk (48,654 residents), Pohnpei (36,196), Yap (11,377), and Kosrae (6616) [5,7,9].

2.2. Outbreak

FSM was assisted by CDC in investigating suspected cases, identifying contacts, conducting analyses to guide outbreak vaccination response, and reviewing vaccine cold chain practices. Complementary funds to assist in the outbreak response were provided by CDC, WHO, and UNICEF. From February 16, 2014 through August 2014, three of FSM's four states reported measles cases: Kosrae (139 cases), Pohnpei (251), and Chuuk (3). In Kosrae and on the mainland of Pohnpei, cases were reported in all municipalities; in Chuuk only one municipality (out of 40) reported cases. Although 16 suspected cases were investigated in Yap, these cases were ruled out following negative laboratory results. Cases were identified by febrile rash illness surveillance at the hospital, contact tracing, and a retrospective investigation of earlier fever and rash cases [7,10].

Median age of cases was 24 years, with 250 (64%) cases aged >19 years. Among adult cases aged 20 years, 49% had received 2 doses of measles-containing vaccine. Measles incidence was lower among children than adults, except infants <12 months who were too young for vaccination. Attack rates were highest for infants (22 cases per 1000 population), followed by adults aged 20–29 years (seven per 1000), and 30–39 years (six per 1000) [7].

2.3. Cost analysis

We defined the analysis period as May 1, 2014, two weeks prior to the first case of measles was reported to the CDC to encompass the incubation period, through December 10, 2014, when the vaccination campaign was completed [1,7,11]. This analysis uses standard cost analysis methods [12]. Costs of the 2014 outbreak were retrospectively collected and categorized into three main categories: (1) outbreak containment costs, (2) direct medical and non-medical costs, and (3) productivity losses (Fig. 1). Costs were collected from the FSM Department of Health, CDC, the FSM Office of Statistics, Budget and Economic Management, Overseas Development Assistance and Compact Management (SBOC), UNICEF, WHO, Feds Data Center, the International Monetary Fund (IMF), and the World Bank (Appendix 1, Table 1).[9,13-20] All expenses are in 2014 US dollars [21].

2.4. Containment

Containment activities were comprised of both an outbreak investigation and a mass vaccination campaign. Outbreak investigation efforts included contact tracing, conducting a retrospective review of prior fever and rash cases, conducting vaccination record checks, and assessing vaccine storage and handling practices. Further, samples had to be shipped and reshipped to different labs in either Guam, Hawaii, or Atlanta. This required significant person hours spent getting these samples to and from the airports and repackaging them for shipment.

To interrupt transmission and contain the outbreak, the mass vaccination campaign was launched successively in each FSM state pursuing children as young as age 6 months through adults up to age 57 years. In Kosrae, the campaign included vaccination record checks and only persons who did not have two documented doses of MCV were vaccinated. Campaigns in Pohnpei and Chuuk targeted all persons 6 months through 49 years of age, without checking vaccination status. In Yap, persons age 19–49 years were vaccinated without checking vaccination records, but those age 1–18 were vaccinated only if they did not have two documented doses of MCV [7]. The campaign targeted 82,472 individuals—80% of the national population. Because FSM includes 607 dispersed islands spanning 1700 miles, numerous boats were necessary as the primary mode of transportation for the outreach vaccination teams. When boats could not reach the shore during low tides, immunization staff had to carry the campaign supplies over the reef. Further, fixed and outreach vaccination posts were set up, as well as mobile vaccination units and door-to-door efforts, which were utilized to immunize hard-to-reach populations, such as isolated communities inhabiting mountainous terrain [10].

During the outbreak, eleven CDC employees were deployed to FSM, with one individual traveling twice to FSM. Non-deployed CDC staff worked over two-thousand hours, primarily conducting laboratory specimen testing. Approximately 32 individuals in Pohnpei, 44 in Chuuk, 20 in Kosrae, and 16 in Yap, composed of nurses, health assistants, data assistants, and health educators, participated in the vaccination campaign spanning nearly 5 months. Nine individuals from FSM participated in the vaccine coverage assessment.

Aside from boat rentals, other transportation costs included car rentals, airfare, fuel, departure fees, and shipping of vaccines and supplies. A total of 79,150 doses of vaccine were purchased by the US; 55,960² pediatric doses and 23,550 adult doses. UNICEF also supplied 10,000 additional doses of MR vaccine (for ages 25 yrs – 49 yrs) and 2620 MR doses on hand were used. A public awareness campaign was implemented, including radio announcements and posters.

2.5. Direct costs

Direct medical costs can be defined as those costs incurred to secure medical treatment, such as hospitalization. Direct nonmedical costs are direct costs incurred in connection with a health outcome, such as shipment of specimens for testing. For this study, direct medical costs included hospitalization and non-hospitalization treatment and medication costs. Direct non-medical costs included laboratory specimen testing, supplies, shipping, and labor. Due to limited capacity to perform diagnostic tests for measles, samples were sent to laboratories in Atlanta, Guam and Hawaii for confirmation. Consequently, lab shipment costs were incurred, in addition to labor and materials. Hospitalization and non-hospitalization costs included treatment, evaluation, case management, medications, and hospital bed occupation fees.

2.6. Productivity losses

Productivity losses are costs foregone due to disability or death resulting from a health problem, such as absenteeism, job loss, or reduced productivity while at work (presenteeism). These costs are essentially the value of resources lost to society due to an ill employee. They also may include resources lost to society due to an employee caring for an ill person, such as a parent missing work to care for a sick child. Typically, productivity losses due to illness or injury include gross earnings calculated using the human capital approach, including payroll taxes and employer paid benefits to capture the full cost of employee compensation. Imputed household earnings are also generally included as part of productivity losses.

To value lost productivity due to death, we apply the value of statistical life (VSL); the amount of money a society is willing to spend to save a life. According to a study by Hammit and Robinson (2011), U.S. regulatory agencies have well-established approaches for estimating the base VSL [22]. Further, international studies have relied on this same research for their base estimates. These base estimates are derived largely from wage-risk studies conducted in the U.S. and other high income countries. We apply the U.S. Department of Transportation's (DOT's) estimate of \$9.1 million (2014\$) [23], which relies on one wage-risk study [24] and four meta-analyses [25-28]. VSL represents individuals' willingness to exchange income for small changes in mortality risks. Therefore, VSL should increase as income increases, but the increase may not be proportional [22]. Therefore, following Hammit and Robinson (2011)), a sensitivity analysis is applied to the income

²Vaccine funding via the CDC is awarded directly to contracts with vaccine manufacturers. FSM ordered the vaccines via the CDC online ordering system (VTrckS). The centralized distributor fills, packs, and ships the order. FSM might have ordered vaccines at a cheaper price through UNICEF using local funds, but timing of procurement may have factored into the decision process. A CDC contracted distributor will deliver within a week of placing the order, whereas ordering through UNICEF can take up to two months.

elasticity when transferring values from the US to FSM [22]. We apply elasticities of 1.0, 1.5, and 2.0. The VSL estimate should be bounded below by estimates of future income or consumption. Due to lack of data on consumption, we bound below only by future income.

3. Results

Total costs incurred as a result of the 2014 Measles Outbreak were nearly \$4,000,000. Although vaccines were the largest driver of costs for the total outbreak, FSM labor costs dominated their economic burden of the outbreak (Table 2, Fig. 2).

Labor costs, for both the outbreak investigation and vaccination campaign, incurred by the US totaled approximately \$80,000. For FSM, these labor costs were over \$300,000. The bulk of containment costs were the vaccine purchase by the US, totaling nearly \$2 million. UNICEF also provided 10,000 adult doses of vaccines (Table 1). FSM incurred car and boat rental and fuel charges as part of the outreach vaccination, as well as travel costs between states, contributing a total of \$94,000 to FSM's containment expenses. WHO contributed \$80,000 toward logistical costs of the vaccination campaign. In total, \$3.5 million was incurred in containment expenses by FSM, the US, UNICEF, and WHO (Table 2).

A total of \$141,000 in direct medical and nonmedical costs were incurred during the outbreak (Table 2). Laboratory testing labor, materials, and shipping were incurred by the US, totaling nearly \$99,000. Hospitalization and non-hospitalizations costs were incurred by FSM, totaling almost \$42,000.

Productivity losses included the value of resources lost to society due to death or illness. For losses due to illness, an average daily wage of \$31.65 is applied. Two-thirds of the diagnosed cases were identified as adults of working age. For the remaining adolescent and infant cases, we assume informal caretaker time was incurred by at least one parent. An average daily wage of \$31.65 is applied to the caregiver time. Of the 393 diagnosed cases, 124 cases were hospitalized. Assuming the more severe cases (inpatient) will not be able to work for 15 working days (or a parent is caring for an adolescent or infant) results in lost productivity costs of approximately \$59,000. Assuming a more conservative period of five lost working days (by the patient or caregiver) for outpatient cases ($n = 269$) results in lost productivity costs of approximately \$42,500 (Table 2).

One infant (21 months old) fatality from measles occurred in the state of Pohnpei. The result (Table 3) is a lost productivity estimate ranging from \$2.3 million to \$37,000, an average of \$584,000. Conservatively, we estimated lost productivity due to death as \$148,000 (income elasticity = 1.5).

4. Discussion

Total costs incurred as a result of the 2014 Measles Outbreak were nearly \$4,000,000; approximately \$10,000 per case. These costs were incurred by agencies within FSM, CDC, WHO, and UNI-CEF. Not surprisingly, vaccines dominating the cost for the total outbreak (Table 2). Further, 99% of FSM labor costs were incurred in the vaccination outreach. A

vaccination campaign often comprises a significant portion of the total costs incurred in responding to vaccine-preventable disease outbreaks [29].

Containment costs (outbreak response and vaccination campaign) comprised 90% of the costs of the outbreak. Many of these costs were attributed to the geographic constraints of the region, but pale in comparison to the cost of the vaccines. The US paid for 66% of the containment costs (85% of the vaccine purchases), while FSM paid 22%, and together UNICEF and WHO paid 11% (Table 2).

Direct costs totaled approximately \$140,000 with 70% paid for by CDC in laboratory testing materials and labor. The remaining 30% were inpatient and outpatient costs incurred by FSM. All productivity losses were incurred by FSM, totaling nearly \$250,000 (6% of total costs).

Of the total cost of the outbreak (nearly \$4 million), FSM paid 22% (approximately \$847,742). To illustrate this impact from FSM's perspective, FSM's total cost of the outbreak is approximately equivalent to FSM's Fiscal Year 2016 Department of Education budget (\$849, 723) [30].

The US paid 67% of the total outbreak costs and together UNICEF and WHO paid 11%. Although the US paid the majority of the costs, these costs must be put into perspective relative to the US and FSMs respective economies. The US 2014 gross national income (GNI) (PPP)³ was \$17.8 trillion, while FSMs GNI (PPP) was \$373 million. Considering the expenses incurred in proportion to each county's GNI, the US paid 0.00001% and FSM paid 0.23% (Table 4).

5. Limitations

While examining the results of this study, there are several limitations that should be taken into consideration. First, due to lack of data, many costs were excluded. For example, time lost and travel costs of the patients seeking healthcare are not included in our analysis. Second, in the productivity cost component of the cost of outbreak, payroll taxes and employer paid benefits are not included in gross earnings, nor are imputed household earnings. Both of these limitations likely underestimate the true costs of the outbreak. Third, we used many proxies for true costs or donations. For example, for the majority of supplies utilized in the mass vaccination campaign, costs were extracted from the published UNICEF price lists; there is no consideration of price markup. Also, wages are the averages for the country; we did not have access to patient level wage data. Lastly, we do not consider costs incurred to the US from the 59 imported cases. Chen et al. (2011) studied the importation response costs of a predominantly health care-associated measles outbreak involving 14 cases [31]. They estimated that two hospitals spent US\$799,136 responding to and containing 7 cases in their facilities; representing a mean cost of \$105,347 per case at

³Purchasing power parity (PPP) conversion factors take into account differences in the relative prices of goods and services—particularly non-tradables—and therefore provide a better overall measure of the real value of output produced by an economy compared to other economies. PPP GNI is measured in current international dollars which, in principal, have the same purchasing power as a dollar spent on GNI in the U. S. economy. (World Bank).

hospital A and \$167,052 for 1 case at hospital B. Averaging these costs across the 14 cases results in approximately \$57,000 per case. Using this estimate would add over \$3 million to the cost of the FSM measles outbreak.

6. Implications

FSM is a lower-middle income country with an economy more susceptible to the negative consequences of harmful events such as the 2014 measles outbreak. According to the World Bank, because FSM is a narrowly-based economy with large distances to major markets, the country is vulnerable to exogenous shocks, which can affect growth and often lead to a high degree of economic volatility [20]. During 2010 and 2011, WHO supported FSM in performing a climate change and health vulnerability and adaptation assessment. Infectious diseases were among the highest priority climate-sensitive health risks identified in FSM [32]. We demonstrate that although FSM was heavily assisted by the US in responding to the 2014 measles outbreak, the outbreak significantly affected their economy.

In the case of the 2014 FSM measles outbreak, vaccine failure among previously immunized individuals appeared to facilitate transmission. Failure of vaccine effectiveness has been identified as a source of the outbreak [5,7]. In response to the outbreak, Hales et al. (2016) studied low vaccine effectiveness in adults in the state of Pohnpei finding vaccine suboptimal storage and handling of MCV may have caused the low vaccine effectiveness [5]. CDC provides recommendations on storage and handling of vaccines; vaccines must be stored properly from the time they are manufactured until they are administered, which is a shared responsibility among manufacturers, distributors, public health staff, and healthcare providers [33,34]. CDC is working with FSM to expand, develop, and strengthen vaccine management. In addition, outbreaks of measles often occur in communities with low vaccination coverage, where many individuals have not received the vaccine [7,35-37]. It is critical to ensure vaccination coverage is kept at optimal levels. School requirements have been linked to increased vaccination coverage [38,39]. Under Code of the Federated States of Micronesia Title 41, Chapter 4, “no child shall attend any school within the Federated States of Micronesia unless such child shall have presented to an appropriate official of the school, a certificate of immunization against such communicable diseases as may be specified by the Department of Social Services in accordance with the provisions of section 405 of this chapter.” The emergency mass vaccination campaign conducted during the outbreak assisted with providing protection to the people of FSM; strengthening enforcement of school vaccination requirements will help maintain high vaccination coverage.

The economic burden of the vaccine failure and ultimately, the outbreak, to FSM coupled with the unique relationship between FSM and the US underscores the need for further research on the cost-effectiveness of interventions that could have prevented the outbreak, such as conducting serosurveys and improving vaccine management. We propose further research to identify (1) the additional consequences of controlling the outbreak to a unique, island economy (i.e. long-term macro effects, imported cases to the US) and (2) the value of avoiding these consequences through varying levels of intervention (i.e. quarantine, various targets of vaccination).

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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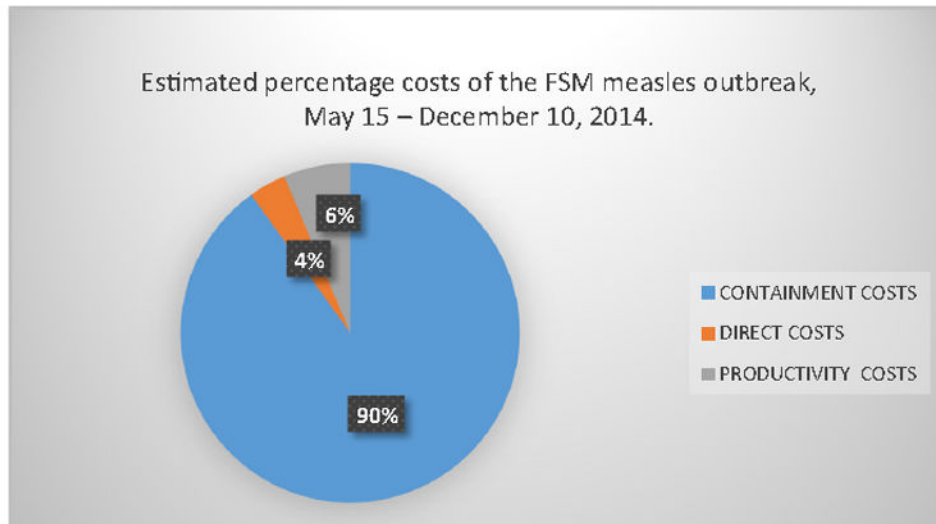


Fig. 1. Costs of the 2014 Federated States of Micronesia Measles outbreak retrospectively collected and categorized into three main categories: (1) outbreak containment costs, (2) direct medical and non-medical costs, and (3) productivity losses. Costs were collected from the FSM Department of Health, the CDC, the FSM Office of Statistics, Budget and Economic Management, Overseas Development Assistance and Compact Management (SBOC), UNICEF, WHO, Feds Data Center, the International Monetary Fund (IMF), and the World Bank [9,13-20].

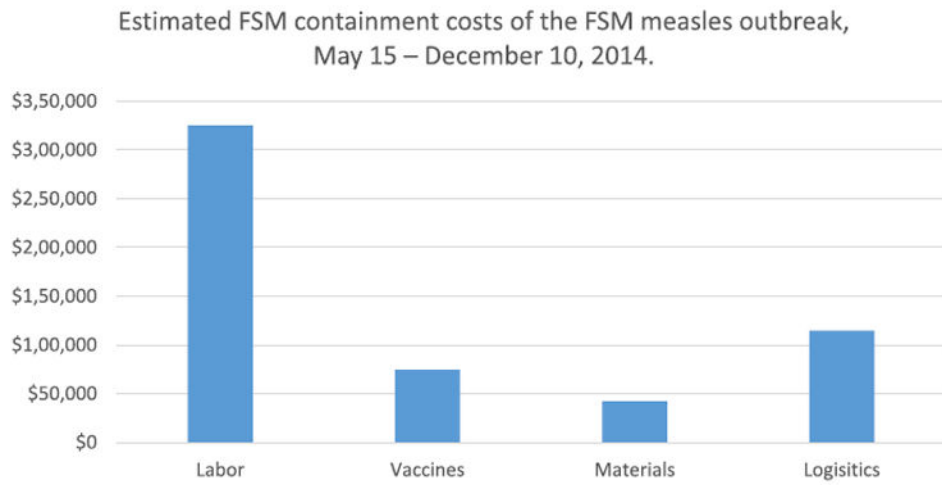


Fig. 2. Labor, vaccines, materials, and logistics costs related to the containment of the 2014 Federated States of Micronesia Measles outbreak retrospectively collected. Costs were collected from the FSM Department of Health, the CDC, the FSM Office of Statistics, Budget and Economic Management, Overseas Development Assistance and Compact Management (SBOC), UNICEF, WHO, Feds Data Center, the International Monetary Fund (IMF), and the World Bank [9,13-20].

Table 1

Estimated resources and costs of the containment of the FSM measles outbreak, May 15 – December 10, 2014.

| Variable | FSM | US | WHO | UNICEF | Total |
|---|-----------|-------------|----------|-----------|-------------|
| <i>Labor</i> | | | | | |
| Approximate number of personnel directly involved | 110 | 14+ | | | 124+ |
| Approximate personnel hours | 3032 | 1728 | | | 4760 |
| <i>Vaccine doses</i> | 2620 | 79,510 | | 10,000 | 92,130 |
| <i>Materials</i> | | | | | |
| Ice lined refrigerators | 3 | | | | 3 |
| Freezers | 5 | | | | 5 |
| Domestic refrigerators | 5 | | | | 5 |
| Cold boxes | 21 | | | | 21 |
| Vaccine carriers | 52 | | | | 52 |
| <i>Estimated costs (US\$)</i> | | | | | |
| Labor | \$325,094 | \$79,652 | | | \$404,745 |
| Vaccines | \$74,664 | \$1,987,526 | | \$370,854 | \$2,433,044 |
| Materials | \$42,000 | | | | \$42,000 |
| Logistics | \$114,597 | \$490,833 | \$81,411 | | \$686,841 |
| Total Costs | \$556,355 | \$2,558,010 | \$81,411 | \$370,854 | \$3,566,630 |

Estimated resources and costs of the containment of the 2014 Federated States of Micronesia Measles outbreak paid by the Federated States of Micronesia, the United States, United Nations Children's Emergency Fund, and World Health Organization.

Table 2

Estimated costs by type and payer for the FSM measles outbreak, May 15 – December 10, 2014.

| | FSM | US | WHO | UNICEF | Subtotal Cost |
|-----------------------------|-----------|-------------|----------|-----------|---------------|
| Containment | | | | | |
| Labor | \$325,094 | \$79,652 | | | \$404,745 |
| Vaccines | \$74,664 | \$1,987,526 | | \$370,854 | \$2,433,044 |
| Materials | \$42,000 | | | | \$42,000 |
| Logistics | \$114,597 | \$490,833 | \$81,411 | | \$686,841 |
| Subtotal | \$556,355 | \$2,558,010 | \$81,411 | \$370,854 | \$3,566,630 |
| Direct | | | | | |
| Medical | \$41,838 | | | | \$41,838 |
| Non-Medical | | \$98,825 | | | \$98,825 |
| Subtotal | \$41,838 | \$98,825 | \$0 | \$0 | \$140,663 |
| Productivity | | | | | |
| Patient (or caregiver time) | \$249,549 | | | | \$249,549 |
| Subtotal | \$249,549 | \$0 | \$0 | \$0 | \$249,549 |
| Total | \$847,742 | \$2,656,835 | \$81,411 | \$370,854 | \$3,956,842 |

Estimated (1) containment costs, (2) direct costs, and (3) productivity costs of the 2014 Federated States of Micronesia Measles outbreak paid by the Federated States of Micronesia, the United States, United Nations Children's Emergency Fund, and World Health Organization.

Table 3

Extrapolated VSL Compared to Future Income (2014\$, 3 percent discount rate, PPP).

| Country | Annual Per Capita GNI | Midpoint Life Expectancy | Future Income | Extrapolated VSL | |
|---------|-----------------------|--------------------------|---------------|------------------|-------------|
| | | | | 1 | 2 |
| US | \$55,900 | 39 | \$1,282,753 | \$9,100,000 | \$9,100,000 |
| FSM | \$3590 | 35 | \$76,570 | \$584,419 | \$37,532 |

Extrapolated Value of Statistical Life compared to future income (2014\$). U.S. Department of Transportation's estimate of \$9.1 million (2014\$) [23] is utilized as the base case. Elasticities of 1.0, 1.5, and 2.0 are applied. The VSL estimate should be bounded below by estimates of future income or consumption. Due to lack of data on consumption, we bound below only by future income. Life expectancy (LE) at mid-point age. Present value of future income, discounted at 3 percent.

Table 4

Estimated cost of the 2014 FSM measles outbreak to FSM and the US relative to each respective economy (2014\$).

| | Cost of Outbreak (COO) | GNI PPP | COO relative to country economy |
|-----|-------------------------------|----------------------|--|
| FSM | \$847,742 | \$373,216,892 | 0.22714% |
| US | \$2,656,835 | \$17,823,200,000,000 | 0.00001% |

Estimated total costs of the 2014 Federated States of Micronesia Measles outbreak paid by the Federated States of Micronesia and the United States, the United States 2014 gross national income (GNI) (PPP), the Federated States of Micronesia GNI (PPP) and costs incurred in proportion to each country's GNI.

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