**Appendix to Preterm Birth Lifetime Costs in the United States in 2016: An Update**

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**Methods for Updating Estimates of the Societal Costs of Preterm Birth to 2016 (A) and Decomposing the Change in Estimated Total Costs, 2004-2016 (B)**

**A. Overview of methods for updating estimates of societal costs**

The method for estimating total cost associated with preterm birth in the United States in a given year, whether 2004 or 2016, is characterized broadly as multiplying per capita lifetime cost of preterm births by the number of those born preterm in a single (or “incident”) birth cohort to yield aggregate preterm costs. All costs are "incremental," that is, costs net of those for term or post-term births (37 weeks or greater), the so-called "referent case." Changes in total costs between a base year (BY), e.g., 2004, and another year, e.g., 2016, can reflect changes in both cohorts and prices.

A general summary of the methodology is outlined in steps 1-6 below.

1. For each cost component (CC) for which estimates were generated (medical care, special education, early intervention services, lost productivity, etc), we begin with per capita costs in a BY (PCby) used to generate estimates for the IOM report on Preterm Birth (Institute of Medicine, 2007). The BY for cost estimates can vary by CC, depending on the data source. The IOM report adjusted cost estimates to 2005 prices for the 2004 birth cohort. Each PCbyx is estimated for each age x of the lifespan for which incremental costs are nonzero (and for which there was adequate available data). Each PCbyx, for each CC, was generated by gestational age (GA) category (<28 weeks, 28-31 weeks, 31-36 weeks, and 37 weeks or more). Section A1 documents the data sources and methods used in the preparation of estimated lifetime incremental cost per infant born preterm in 2004.

i. discounting of costs beyond the birth year—Each PCbyx cost incurred at age x was discounted back to the year of birth at a 3% rate, or divided by 1.03x, to express such costs in terms of present value.

ii. incremental costs—Each PCby at GA 37 weeks or more (term or post-term) was subtracted from PCby by preterm GA category to yield an incremental PCby by GA category within each CC for those born preterm.

iii. conversion to national PCsn—In instances where cost data for a PCby cost category was drawn from a specific state (Utah for medical care costs through age 5 and maternal delivery costs, and Massachusetts for early intervention services), a state-specific geographic adjustment factor (GAF) for that CC in the base year was applied to yield a national PCby. This adjustment was part of the methodology incorporated in the original IOM report.

2. The national PCby for each CC was multiplied by the value of the change in the national price index corresponding to each CC (PIcc) between the relevant BY and 2016 to yield national GA- specific PCs in 2016 dollars (PC16) for each CC. Section A3 documents the methods and data sources for step 2.

3. The PC16x at each age x for each CC by GA category was multiplied by the estimated numbers of survivors in the nation to each age x in 2016 (S16x) to yield CC-specific aggregate costs (ACx16) at each age by GA category in 2016. Section A2 documents methods used to estimate the numbers of infants born in 2016 by GA and numbers of survivors projected in future years.

4. The summation of age-specific ACs16x over all ages yielded CC-specific lifetime aggregate costs (AC16) by GA category for the 2016 preterm birth cohort.

i. division by the total number of preterm births nationally in 2016 (TBn) by GAn yielded CC-specific national per preterm birth cost (PTBn) by GAn in 2016.

5. Summation over all preterm GA categories yielded CC-specific all preterm Aggregate Costs (PACn).

i division by TBn yielded CC-specific per preterm birth cost for the nation (PTBn)

6. Summation over all CCs yielded grand total national preterm birth costs (GTNCn)

i. division by TBn yielded grand total national per preterm birth costs (GTPTBn)

A1. ***Base Year Per Capita Costs by Cost Category (PCby by CC)***

As noted above, per capita costs in the base year (PCby) by CC and GA category formed the basis for the adjustments to per capita costs in 2016 (PC16). This subsection provides an overview on methods specific to the cost categories and the sources of data for each category used in the 2007 IOM report and the update.

*Cost Categories (CC)--* Direct costs of preterm birth were estimated for all infants born preterm for a) medical care services from birth through age 5, b) maternal delivery inpatient services through discharge after delivery, and c) publicly provided early intervention services for the first 3 years of life. Estimates for other cost categories (medical care beyond age 5, special education at ages 3-17 years, home and vehicle modifications, and lost productivity at ages 18-64) were estimated for the preterm population diagnosed with one of four developmental disabilities (DDs): intellectual disability (ID, also referred to as mental retardation), cerebral palsy (CP), hearing loss and vision loss. Using the presence of a DD as a filter to estimate cost beyond age five was necessitated by the absence of longitudinal (lifetime) data on costs exclusive to the preterm birth population as a whole. Data was available, on the other hand, for the incremental incidence of DDs by GA and cost by DD, which permitted the generation of cost estimates for the sub-population of those born preterm with any of the four DDs for the cost categories noted above.

*Raw Data by Cost Category—*The raw data for base year per capita cost estimates by cost category (PCby) were those used for cost estimates in the IOM report on preterm birth. A brief review of that data is provided here, but the reader is directed to chapter 12 of that volume on the societal cost of preterm birth (pp 398-429) for a more in-depth review of estimates underlying base year per capita costs by cost category.

Medical Care Costs to Age 5—The data for estimates of medical costs through age 5 years came from administrative claims and reimbursement records for the 1998-2000 birth cohorts (23,631 births) covered under an Intermountain Healthcare (IHC) closed panel plan in Utah followed for up to seven years. The estimates from this data were subjected to validation relative to other less robust preterm- and low birthweight-specific estimates available at the time.

Maternal Delivery Costs—Data for these estimates came from the maternal delivery administrative records for the births described above from IHC.

Early Intervention (EI) Services Costs—Data for cost estimates from publicly provided EI services in the first 3 years of life were from Massachusetts (Clements et al., 2007).

Costs associated with Developmental Disabilities (DDs)—Data on the incremental risk for prematurity by GA category for one of the four DDs (ID, CP, vision loss, and hearing loss) came from the Centers for Disease Control and Prevention’s (CDC’s) Metropolitan Atlanta Developmental Disabilities Surveillance Program (MADDSP) for survivors at age 3 of the 1981-1991 birth cohorts in the metropolitan Atlanta region through age 10 (Boyle et al., 1996). (<https://www.cdc.gov/ncbddd/developmentaldisabilities/maddsp.html>).

Methods and data sources for estimation of incremental per-person costs for individuals with a DD by age and by cost category (medical care beyond the age of 5, home and vehicle modifications, special education services, and productivity losses) are described in Honeycutt et al. (2003). Costs associated with included DDs were estimated for 6 age groups: 0-5, 6-17, 18-25, 26-34, 35-64, and 65-76 years.

Medical costs associated with the four DDs were inclusive of hospital inpatient stays, physician visits, prescription medications, long-term non-institutional care in adults (ages 18-76 years), therapy and rehabilitation services in children (ages <18 years), and assistive devices. Utilization data for each DD came from the 1994 and 1995 National Health Interview Survey (NHIS) and NHIS Disability Supplement (NHIS-D). Costs of hospitalizations were based on 1995 hospital charges multiplied by Medicare cost-to-charge ratios, and unit costs for physician visits and prescription medications were taken from the 1987 National Medical Expenditure Survey (NMES), adjusted for subsequent medical inflation using Medicare reimbursements. Unit costs for other medical costs were based on vendor prices, national compensation survey data for therapists, and daily costs of care from intermediate care facilities. Two types of medical costs that were not included were hospital outpatient services and long-term institutional care.

Percentages of children receiving special education services were taken from 1991 MADDSP data, with placement types from 1994-1995 NHIS-D data. Costs for special education placements relative to regular education were based on a 1988 survey, adjusted for inflation using the ECI for public sector workers. A relatively small direct cost component, home and vehicle modifications, was likewise based on utilization from NHIS-D data in combination with annualized vendor prices.

Indirect costs associated with productivity losses in working-age adults with DDs (18-25, 26-34, and 35-64 years) due to heightened morbidity and excess mortality from birth through age 64 were calculated in two parts. Disability costs were assessed by multiplying the proportions of working-age adults who reported in the NHIS-D being unable to work or limited in the work they could perform by the percentage reductions in earnings associated with work limitations based on the 1993 Survey of Income and Program Participation and average gross earnings by age and sex for the US population reported by Grosse (2003). The opportunity cost of premature mortality associated with DDs in working-age adults was calculated as the product of the cumulative difference in mortality from birth to the age group associated with each DD multiplied by average earnings in the age group. Survival estimates between 6 and 17 years for each DD were based on excess relative mortality from Decoufle and Autry (2002). For ages 1 to 5 and beyond age 17, individuals with ID and CP excess mortality ratios relative to US life tables were taken from California data analyzed by Strauss and Eyman (1996) and Singer et al. (1996), respectively. Infant mortality was assumed to be the same as the general population, as was adult mortality for individuals with hearing or vision losses.

A2. ***Cohort Estimates (TBn and Sn ) in 2016***

Under the incidence approach to the cost of illness undertaken for this study, cost estimates are generated across the lifespan for each individual born preterm by GA category. As indicated in the introductory section to this Appendix, per capita costs were multiplied by cohort estimates at each age. Cohort estimates by age (S) and GA are therefore required for national cost estimates. In other words, the birth cohort by GA is required coupled with mortality/survival estimates to yield S for each age x.

*Birth Cohort--*The data for preterm birth rates and numbers of preterm births by GA for the nation and each state were taken from vital statistics linked birth/death records compiled by the National Center for Health Statistics (NCHS)--<https://wonder.cdc.gov/lbd.html>. The 2016 birth cohort served as the basis for all estimates, as data for that cohort was the latest available at the inception of the study.

*Infant Cohort*—As noted above, data were required for eachage across the lifespan for which cost estimates were available. Therefore, mortality data by GA were required to generate the size of the cohort by GA at each age. Of particular import for preterm birth is infant mortality, given both the high concentration of costs in the first year of life and the well-documented elevated rate of infant mortality associated with preterm birth. Infant mortality rates and the number of infant deaths by GA for the 2016 cohort at the national and state levels were taken as well from the linked birth-death record database compiled by the NCHS--<https://wonder.cdc.gov/lbd.html>.

Given that medical costs are concentrated not just in the first year of life, but in the first few months of life, the analysis took advantage of the fact that infant mortality from the NCHS database was parsed into neonatal and post-neonatal mortality rates by GA, permitting a more granular adjustment to estimates of infant medical care costs.

Raw data on medical cost in infancy were available by month, so the infant cohort was adjusted for neonatal and post-neonatal mortality separately. This was performed with a discrete function. All infants were assumed to contribute to costs in the first month; neonatal mortality was fully applied to the cohort after the first month of life, so the infant cohort consisted strictly of post-neonatal survivors after the first month; post-neonatal mortality was fully applied after the third month, so the cohort consisted strictly of those surviving infancy from the fourth to twelfth month of life.

*Cohort estimates beyond infancy—*Mortality was assumed to revert back to population mortality rates after infancy except for those with one of the four DDs. Population mortality rates were taken from NCHS vital statistics (<https://ftp.cdc.gov/pub/Health_Statistics/NCHS/Publications/NVSR/68_04/>) to generate cohort size at each age after infancy by GA for those with no DD. Survival estimates for those with DDs are discussed in section A1.

**A3. *Price Adjustments to 2016 and Geographic Adjustment Factors (PIs and GAFs)***

***Updating prices and costs to 2016****—*Costs in the IOM report were expressed in 2005 dollars ($ 2005) for the nation. These costs were often inflated to 2005 from a prior base year or range of years covered by the raw data. Since cost estimates reflected the base year's per capita cost distribution by GA and by age, it was desirable from the standpoint of accuracy to use the base year's costs as the starting point to adjust to 2016 costs. Cost adjustments to 2016 were tailored to specific cost categories, some more narrowly than others. The following provides a discussion of methods for updating costs by cost component.

Medical Cost--Given its pronounced importance in the cost estimates and its notorious historical departures from general price movements and variation, medical service costs were adjusted separately from other cost categories. Indeed, within medical care, dedicated adjustments were made for inpatient and outpatient medical service costs separately, given the significant variation in price movements between them and the disproportionate share of medical care comprised of inpatient services for preterm infants. Indices used to adjust prices over time are discussed here. Geographic adjustment factors (GAFs) used to adjust costs at the state level to the nation for two service categories are provided in the section below dedicated to that topic.

*Inpatient*--The Producer Price Index PPI index tailored to general inpatient care was used to adjust for changes in national inpatient costs to 2016. More specifically, the change in the "PPI by Industry: General and Surgical Hospitals" (https://www.bls.gov/ppi/) from 1998 to 2016 (a factor of 1.675) was applied to national per capita costs by GA by age in to arrive at per preterm birth costs by GA by age in 2016. The PPI is designed to reflect actual, or "transaction" prices paid by public and private payers to hospitals for inpatient services.

*Outpatient Services and Prescription Medications--*The "Personal Consumption Expenditure" Index for health (PCE-Health) was used analogously as the PPI to adjust for changes in national outpatient costs by GA by age from 1998 to 2016

(https://meps.ahrq.gov/about\_meps/Price\_Index.shtml, table 3), a factor of 1.546. PCE-Health is a chain-weighted, or "Fisher Ideal," index comprised of deflators (price indices) that reflect the composite of services that go into health care.

Medical Costs Associated with DDs -- The price index applied to medical care beyond age five for those with one of four DDs (inpatient services, outpatient services, long term care rehabilitation services, physical therapy, and assistive devices) was constructed as a weighted average of the Bureau of Labor Statistics' Employee Compensation Index (ECI) (60%), the inpatient deflator described above (25%), and the outpatient deflator described above (15%), with the respective weights in parentheses. The weights reflect the average composition of medical services provided to those with one of the four DDs. The costs of listed medical services other than outpatient and inpatient care are composed largely of employee compensation, so the ECI is appropriate to apply.

Other Direct Service Costs --Services other than medical care that were part of the preterm cost calculations, such as special education (SE) and early intervention (EI) services, were largely comprised of compensation to public employees. The ECI government employee sub-component was therefore used as the price index to update national per capita base year costs to 2016 for special education and EI services (<https://www.bls.gov/eci/>).

Productivity Costs -- The general ECI was used to update labor market productivity losses.

***Base Year Geographic Adjustment Factors (GAFs)--***Data for three categories of base year per capita cost estimates for the IOM report (medical care through age 5, maternal delivery costs, and early intervention costs) came from individual states. Estimates for these three categories had to be converted from state to national estimates in the base year using individual state GAFs. They were then adjusted for price increases to 2016 using the national price indices (PIs) reviewed above.

Estimates of medical care cost through age 5 years and maternal delivery costs, as described in A1, came from administrative records on 1998 through 2000 Utah birth cohorts and on maternal records attached to those cohorts. Early intervention services estimates were taken from Clements et al. (2007).

Two sets of GAFs were used to adjust Utah medical costs to the nation, one for inpatient care and the other for outpatient care.

*Inpatient GAF*-- The Centers for Medicare and Medicaid Services (CMS) adjusted Inpatient Prospective Payment System (IPPS) reimbursements to hospitals for geographic differences in inpatient hospital costs at the geographic level of the metropolitan statistical area (MSA) at the time of the IOM report. MSAs are one or more contiguous counties of 50,000 population with economic ties. IPPS payments consist of a combination of two components, an operating component, based on a hospital wage index (HWI) reflecting personnel and supply costs, and a capital component, reflecting interest payments and depreciation. The capital component is equal to a simple transformation of the HWI. Recent summaries of the algorithms for constructing these components of the inpatient GAF is provided by the Medicare Payment Advisory Commission (MedPac, 2016) and the Department of Health and Human Services (https://oig.hhs.gov/oas/reports/region1/11700500.pdf)

IPPS rates are updated by CMS annually for geographic changes in costs. Since the data were provided at the MSA (plus all other/rural) level and GAFs were desired at the state level, Census population estimates of MSAs (and all other areas/rural) were applied to the area-specific GAFs to generate one Utah-specific inpatient GAFs.

*Outpatient GAF—*The GAFs for outpatient services were based on the geographic practice cost indices (GPCIs) under Medicare's 2016 physician fee schedule (PFS). Physician payment is based on relative value units (RVUs) and divided into three components: a work RVU, a practice expense RVU (PE), and a malpractice RVU (MP). RVUs are converted into dollars according to a conversion factor updated every year by CMS (<https://www.cms.gov/Medicare/Medicare-Fee-for-Service-Payment/PhysicianFeeSched/PFS-Relative-Value-Files>).

Each of the three components of physician expense has a corresponding GPCI, reflecting the market characteristics relevant to each of the expenses. GPCI data by area for each component were available from <https://www.cms.gov/apps/physician-fee-schedule/search/search-criteria.aspx>. General weights of the RVUs among the three practice expenses were applied to the three GCPIs by area to generate area-specific weighted GCPIs. Beneficiary population by CMS were used as weights applied to these areas to generate a single weighted GCPI, or outpatient GAF for Utah.

*Early Intervention Services*--The GAF applied to Massachusetts (MA) early intervention costs to generate national estimates was based on a weighted average of American Chamber of Commerce Research Association (ACCRA) cost of living indices (COL) for metropolitan and non-metropolitan areas in MA using area population as weights to create a single GAF.

**B. Decomposition of Factors Driving Changes in Total Costs from 2004 to 2016**

The estimated total cost of preterm birth for the nation in 2004, at $26.2 billion in 2005 dollars, paradoxically *exceeded* the $25.2 billion total cost in 2016 reported here by $1 billion despite the intervening increases in prices. Several non-price factors contributing to the change in costs of preterm birth between 2004 and 2016 resolve the paradox. Had those non-price factors not changed, the total cost in 2016 would have been $32.0 billion, a $5.8 billion increase over the earlier estimate in nominal (current-year) dollars. This appendix provides the results of a formal decomposition of the contribution of each component factor.

*Factors affecting the change in cost--*The total cost in each year is contingent on 1) the national preterm birth rate; 2) the number of births in the nation; 3) the distribution of births within each gestational age (GA) category, as early preterm births are more costly than late preterm births; 4) the infant mortality rate within GA category; and 5) the prices of services delivered, or costs of lost labor market productivity, associated with preterm births. While an additional factor, the quantity or intensity of services, is also critical to cost, the update of costs provided in the article assumes the level of provision of services for each GA category as in the earlier estimate.

All of the five factors listed above changed between 2004 and 2016\*, thereby affecting the total costs of preterm birth. The major factor increasing cost was 5) the increase in prices and costs (see Appendix A for description of costs and prices). The most significant countervailing factor, acting to decrease cost, was the change in 2014 in the official measure of GA from the LMP (last menstrual period) to the OE (obstetric estimate). The 2016 OE was used for estimates in this analysis whereas the 2003 LMP\* was used for the IOM estimates. The OE and LMP estimates in 2016 were derived from separate data queries from the linked infant and birth records in CDC Wonder online database. Critically, the OE was associated with factor 1) a reduction in the national preterm birth rate, although its adoption also affected factors 3) and 4), as outlined below. But even if the method for assessing GA had not changed from the LMP to the OE, there were other counteracting influences to the increase in total cost associated with the pure price change. There was a decline from 2003\* to 2016 in factor 1) the preterm birth rate using the LMP measure in both years. In addition, there was an overall reduction from 2004 to 2016\* in factor 2) the number of births in the nation. Each of these influences are considered in turn in the decomposition provided in Table B1 and discussed below.

*Pure Price Change*--The first entry in Table B1 summarizes the result of the pure price change from 2004 to 2016 on total preterm birth costs. It assumes only an adjustment for prices to 2016, retaining the number of 2004 births and the 2003 LMP measure (overall preterm birth rate, rate of preterm birth by GA, and rate of infant mortality by GA). As noted above, the resulting total cost is $32 billion.

*Change in the Number of Births--*The second entry in Table B1 estimates the effect of the decrease in the total number of births in the nation from 2004 to 2016, which reduces total costs by $1.3 billion to $30.7 billion, assuming no change in the preterm birth rate.

*Switch to the 2016 LMP*--The third entry in Table B1 summarizes the additional decline in cost, relative to the second entry, associated with the change from 2003 to 2016 in preterm birth rates and GA-specific infant mortality using the LMP measure in both years. The joint change lowers the cost estimate by an additional $1.4 billion to $29.3 billion. That estimate was calculated by substituting the 2016 LMP estimates of the distribution of births and infant deaths by GA for the 2003 values. The $1.4 billion reduction is the net result of two changes summarized in entries 3a), a decline of $2.4 billion due to the lower overall preterm birth rate using the 2016 LMP (11.4%) rather than the 2003 LMP (12.3%), and 3b), an increase of $1.0 billion resulting from the joint effects of changes in the distribution of preterm births and of infant mortality by GA category from the 2003 LMP to the 2016 LMP data. The greatest reductions in preterm births occurred at 35 and 36 weeks of age, and since costs are lower for late preterm births, the shift in the distribution by GA category among preterm births raised average costs per preterm birth, thereby counteracting part of the decline in costs due to the reduced number of preterm births. In addition, the reduction in infant mortality, especially at early gestational ages where costs are most pronounced, resulted in more preterm survivors and greater costs associated with preterm birth, other things constant.

*Switch to the 2016 OE--*The remaining decline of $4.1 billion in total cost, from $29.3 billion to $25.2 billion, is attributable to the change from LMP to OE, specifically applied to 2016 births in our analysis (the fourth bolded entry in the table). This is the net result of two changes as well, 4a) the lower preterm birth rate associated with the 2016 OE (9.8%) relative to the 2016 LMP (11.4%), yielding a decrease of $4.8 billion, and 4b) the change in the distribution of preterm births and infant mortality by GA from the LMP to the OE, yielding an increase of $0.7 billion. The effect of the change in measures was to reduce the share of late preterm births, thereby making preterm births slightly younger on average and hence raising average costs modestly.

Table B1. Decomposition of the Change in total costs of preterm birth from 2004 to 2016

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| --- | --- | --- |
|  | *Description* | *Costs* |
| 1. | **Pure Price Change from 2005 to 2016** | **$32.0 billion** |
| 2. | **Reduction in the Number of Births from 2004 to 2016** | **$30.7 billion** |
| 3. | **Switch to the 2016 LMP from the 2003 LMP\*** | **$29.3 billion** |
| a) | Lower Preterm Birth Rate | - $2.4 billion |
| b) | Change in the Distribution of Preterm Birth and Infant Mortality | + $1.0 billion |
| 4. | **Switch to the 2016 OE from the 2016 LMP** | **$25.2 billion** |
| a) | Lower Preterm Birth Rate | - $4.8 billion |
| b) | Change in the Distribution of Preterm Birth and Infant Mortality | + $0.7 billion |

\*The total cost of preterm birth in the IOM report was expressed in $ 2005 but was based on the number of births in 2004 and the 2003 LMP preterm birth rate by GA (the latest vital statistics available at the time). The 2016 OE and LMP estimates of preterm births in 2016 were taken from the linked infant and births records in CDC Wonder. All reported costs are “incremental”, that is above and beyond the average costs of term and post-term births.

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