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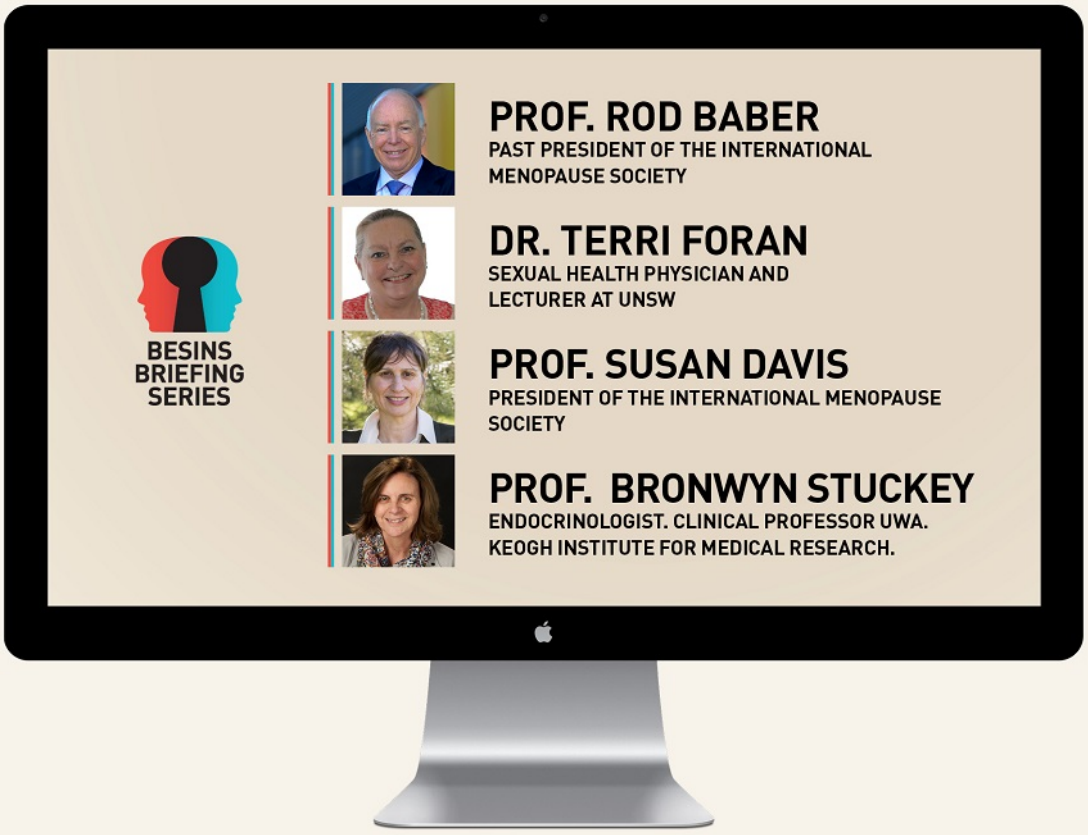


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ORIGINAL ARTICLE

# The health and educational costs of preterm birth to 18 years of age in Australia

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**Background:** Preterm birth is the greatest cause of death up to five years of age and an important contributor to lifelong disability. There is increasing evidence that a meaningful proportion of early births may be prevented, but widespread introduction of effective preventive strategies will require financial support.
**Aims:** This study estimated the economic cost to the Australian government of preterm birth, up to 18 years of age.
**Materials and Methods:** A decision-analytic model was developed to estimate the costs of preterm birth in Australia for a hypothetical cohort of 314 814 children, the number of live births in 2016. Costs to Australia's eight jurisdictions included medical expenditures and additional costs to educational services.
**Results:** The total cost of preterm birth to the Australian government associated with the annual cohort was estimated at $1.413 billion (95% CI 1047-1781). Two-thirds of the costs were borne by healthcare services during the newborn period and one-quarter of the costs by educational services providing special assistance. For each child, the costs were highest for those born at the earliest survivable gestational age, but the larger numbers of children born at later gestational ages contributed heavily to the overall economic burden.
**Conclusion:** Preterm birth leaves many people with lifelong disabilities and generates a significant economic burden to society. The costs extend beyond those to the healthcare system and include additional educational needs. Assessments of economic costs should inform economic evaluations of interventions aimed at the prevention or treatment of preterm birth.

**KEYWORDS**
cost of illness, economic evaluation, health costs, preterm birth, prevention

## INTRODUCTION

Preterm birth represents one of the major challenges to contemporary health care. Being born too early is the greatest cause of death in newborns and a significant contributor to ongoing disability.[1] Birth at the very early gestational ages is associated with increased risk of cerebral palsy, blindness and deafness.[2] Being born at later gestational ages, extending to early term, is associated with increased risk of learning and behavioural disorders at school age.[3] Together, the consequences of preterm birth for individuals, families and societies are considerable, both in terms of human suffering and economic consequences.

The importance of quantifying the economic costs of preterm birth has been highlighted in recent years as a result of prevention becoming a realistic possibility. Several clinical strategies have now shown promise. When applied as a multifaceted program across an entire population the rate of preterm birth can be reduced, at least by about 8%.[4] Further advances in potential interventions can be expected to make prevention even more effective.

Decisions to apply resources to prevention, as opposed to just treatment, are best based on assessments that include reliable economic estimates. Several studies have now been published reporting the considerable annual cost of preterm birth across nations, including England and Wales,[5] Canada[6] and the USA.[7]

The purpose of this study was to estimate the economic cost of preterm birth to the Australian government and provide financial information enabling appropriate decision making in allocating resources to the prevention and treatment of preterm birth.

## MATERIALS AND METHODS

### Overview

A decision-analytic model was developed to estimate the costs of preterm birth in Australia for a hypothetical cohort of 314 814 Australian children born in 2016. The modelling framework was similar to an approach used for England and Wales,[5] and Canada,[6] but adapted for an Australian context. Costs from birth to 18 years of age were estimated from a government perspective, discounted at 3.5% per annum[8] and reported in 2018 Australian dollars. Costs included birth, neonatal, and post-birth discharge hospitalisations; stillbirth government payments; emergency transportation for neonatal care; the Medicare Benefits Schedule (MBS) and Pharmaceutical Benefits Schedule (PBS); and government schooling for primary and secondary education.

### Model framework

The live cohort enters the model from birth in gestational age groups: extremely preterm (20–27 weeks); moderately preterm (28–31 weeks); late preterm (32–36 weeks) and term (≥37 weeks) (Fig. 1). After birth, the majority of neonates are discharged and progress to two years of age. A small proportion die in the delivery room, some are transferred for neonatal care and discharged or die before discharge from neonatal care. Hospitalisations and survivorship are modelled annually from two to 18 years of age. Levels of disability at primary and secondary school are imputed based on the relative risk of special education needs from the literature.

### Model parameters

Australian data were available for the majority of parameters (Tables A1, A2 in Appendix S1). The number of births in each state by gestational age was obtained from the Australian Institute of Health and Welfare (AIHW) perinatal statistics.[9] The probabilities of death in the delivery room and of neonatal admission were estimated for each gestational age group using the AIHW perinatal statistics.[9] The requirement for neonatal emergency transport was set at one in ten neonatal admissions based on an Australian study of infants born outside tertiary centres.[10] The probability of surviving to discharge from the neonatal hospitalisation was estimated for each gestational age group using the Australian and New Zealand neonatal network data.[11] The annual probability of hospitalisation for each gestational age group was derived from an Australian population-based longitudinal study of hospital admissions until 18 years of age.[12] As that study combined gestational ages below 32 weeks, probabilities of hospitalisation for the 20–27 weeks and 28–31 weeks groups were assumed to be equal, with the effects of this assumption tested in a supplementary sensitivity analysis. Survivorship data were obtained from Australian Life tables,[13] with relative risks applied to preterm birth cohorts derived from the literature.[14]

### Healthcare costs

Delivery costs by state were obtained from the Independent Hospital Pricing Authority (IHPA) maternity data, which provides cost and number of separations of each maternity diagnostic related group (DRG) by state.[15] To calculate an average cost of delivery by gestational age group and state, DRGs were weighted by type of birth, length of stay and public or private setting based on the latest AIHW perinatal statistics.[9] Average neonatal admission costs by gestational age group were calculated from IHPA data, weighted according to birthweight based on the latest AIHW perinatal statistics.[9] As IHPA does not provide neonatal DRG data by state, national admission costs were varied by state based on the average variation of all state hospitalisation costs.[16] Newborn emergency transport services vary across Australia; however, there are little data on costs borne by government. An ambulance cost for a 250 km journey in New South Wales, where the government subsidises 49% of costs, was used as a proxy (call-out fee $382 + $3.44/km = $1242/trip)[17] for all gestational age groups.

Primary care costs were derived from the Longitudinal Study of Australian Children which reported the annual MBS and PBS

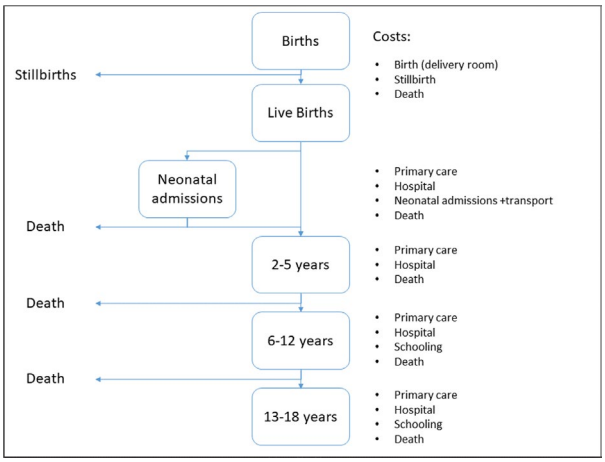


**FIGURE 1** Schematic of the decision-analytic model structure.

costs by gestational age group over 0–5 and 4–9 years.[18] Costs were extrapolated from nine to 18 years of age using the annual estimate during the ninth year of life.

Hospitalisation costs, excluding delivery and neonatal admissions, were obtained from a data request to IHPA for childhood hospital separations.[16] Average hospitalisation costs by gestational age group were calculated from child DRG separations weighted according to the Australian longitudinal study data using hospitalisations that occurred after discharge from the birth-related admission until 18 years of age.[12] Hospital admissions were reported based on the International Classification of Diseases, and mapped to DRGs.[19] Costs for the 20–27 and 28–31 weeks groups were assumed to be equal. Hospitalisations before one year of age were excluded to avoid double-counting with the neonatal admissions; the effects of this assumption were tested in a supplementary sensitivity analysis. The state-specific costs were derived from the national neonatal admission costs using the average variation of all state hospitalisation costs.[15]

Costs of death associated with hospitalisations in the last year of life, estimated from an Australian data linkage study[20] equated to $21 840 (inflating to 2018 dollars). These costs are only applied to deaths; the hospitalisation costs calculated in the previous section excluded those who had died prior to the start of each interval, to mitigate potential double-counting. Costs were varied by state based on the average variation of state costs across all hospitalisations.[15]

## Wider government costs

The Australian government makes a payment of $2200 to eligible parents for a first stillborn child and $1101 for any subsequent stillborn children.[21] AIHW data show that a stillbirth was preceded by one or more stillbirths in 7% of cases.[22] A survey of the families of stillborn children suggests that 22% of families are likely to be eligible.[23] The average cost to government was therefore estimated at $475 per stillbirth.

Since 2018, Australian schools are provided a disability loading with a base rate of $11 343 per primary student increased by 42% for a supplementary level of disability, 146% for a substantial disability, and 312% for an extensive disability. For secondary students, the base rate is $14 254, and the disability loadings are 33, 116 and 248% respectively.[24] The mapping of schooling disability categories was based on the population-based Scottish study of 407 503 children, which linked school census data with gestational age that highlighted the relative risk of special education needs for preterm births of 1.53, 2.66 and 6.92 for late, moderately and extremely preterm cohorts respectively.[25] All costs are summarised in Appendix S1 (Tables A3, A4).

## Analytical methods

Costs were estimated from birth to 18 years of age for each gestational age group and the incremental cost of preterm birth calculated as the difference between preterm cohorts and the term cohort. Results were calculated at national and state levels, and the incremental costs grouped by cost category. A multivariate sensitivity was conducted with 1000 simulations to highlight the estimates uncertainty, and confidence intervals reported the 2.5th and 97.5th percentile results. Cost savings from preterm birth reductions were estimated using a scenario analysis based on 5, 10 and 25% reductions in the number of preterm births across all preterm cohorts.

The study was approved by the Women and Newborn Health Service Human Research Ethics Committee (2016027EW) and the Health Department of Western Australia (EC00422).

# RESULTS

## Incremental costs of preterm births

The incremental cost of an extremely preterm, very preterm and preterm birth relative to a term birth was estimated at $236 036, $89 709 and $25 417, respectively (Table 1).

The major contributors to the incremental cost of preterm births were neonatal admission costs contributing around two-thirds of the cost difference, and schooling costs contributing around a quarter of the cost difference.

The incremental cost differences of preterm birth varied by state, with the Northern Territory, Western Australia and the Australian Capital Territory facing the highest cost differences, while Victoria and New South Wales faced the lowest (Table 2).

## Overall cost burden of preterm births

The overall incremental cost of preterm birth to government was estimated at $1.413 billion for the 2016 birth cohort (Table 3).

**TABLE 1** Incremental cost of preterm birth, by cost category, $ per birth, relative to term birth

| Cost group | Extremely preterm | Moderately preterm | Late preterm |
|---|---|---|---|
| Birth | -$860 | $3657 | $995 |
| | (−3144-1155) | (1045-7217) | (−874-2763) |
| Neonatal admission | $146 469 | $60 876 | $15 927 |
| | (115 927-177 068) | (48 272-74 600) | (13 001-19 376) |
| Primary care | $15 342 | $3270 | $992 |
| | (10 523-21 103) | (2067-4609) | (173-1649) |
| Secondary care | $1151 | $1108 | $829 |
| | (368-1986) | (214-2028) | (242-1341) |
| Schooling | $73 934 | $20 798 | $6675 |
| | (56 457-90 840) | (17 760-24 338) | (5414-7650) |
| Total | $236 036 | $89 709 | $25 417 |
| | (179 539-292 152) | (69 357-112 792) | (17 956-32 779) |

Confidence intervals are indicated in brackets.

**TABLE 2** Incremental cost of preterm birth, total cost differential by state, $ per birth, relative to term birth

| State | Extremely preterm | Moderately preterm | Late preterm |
|---|---|---|---|
| New South Wales | $236 769 | $86 789 | $24 497 |
| | (180 676-287 552) | (68 611-108 648) | (16 453-319 361) |
| Victoria | $224 920 | $83 091 | $23 742 |
| | (172 702-274 990) | (65 080-101 361) | (16 307-31 872) |
| Queensland | $235 372 | $88 908 | $25 307 |
| | (179 741-294 914) | (65 588-109 353) | (17 352-34 018) |
| Western Australia | $275 534 | $104 849 | $29 483 |
| | (212 239-338 172) | (81 831-127 635) | (19 747-38 669) |
| South Australia | $256 598 | $95 041 | $26 874 |
| | (191 834-317 103) | (76 146-114 023) | (19 087-34 179) |
| Tasmania | $236 569 | $90 853 | $25 413 |
| | (177 847-339, 145) | (75 132-131 301) | (20 159-39 997) |
| Australian Capital Territory | $274 353 | $102 755 | $28 867 |
| | (208 567-62 813) | (49 091-150 840) | (178 496-366 338) |
| Northern Territory | $284 921 | $109 442 | $30 968 |
| | (216 812-348 359) | (83 360-136 167) | (20 733-42 186) |
| National (in Table 1) | $236 036 | $89 709 | $25 417 |
| | (179 539-292 152) | (69 357-112 792) | (17 956-32 779) |

Confidence intervals are indicated in brackets.

Of this, 46% was attributable to those born extremely preterm, 15% to those born moderately preterm, and 39% to those born late preterm.

New South Wales and Victoria have the highest numbers of preterm births, with 27 and 26% of all Australian preterm births respectively, with overall burdens of $371 million and $358 million per year (Table A5 in Appendix S1).

Reducing national preterm births by 5% may save the government $71 million per year; reductions of 25% would save $353 million per year (Table 4).

## DISCUSSION

Our estimate of the costs of preterm birth to the Australian government in a hypothetical cohort of 314 814 births in 2016 was found to be $1.413 billion.

Immediate medical and subsequent costs of preterm birth are in general inversely related to gestational age at birth. Extremely preterm births were the most expensive, yielding a total incremental cost of $236 036 each. The incremental cost for each

**TABLE 3** Overall cost burden of preterm birth, by cost group, $ per birth

| Metric | Extremely preterm | Moderately preterm | Late preterm | Total |
|---|---|---|---|---|
| Incremental cost | $236 036 | $89 709 | $25 417 | |
| | (179 539-292 152) | (69 357-112 792) | (17 956-32 779) | |
| Births (*n*) | 2769 | 2302 | 21 743 | 26 814 |
| Cost burden ($m) | $654m | $207m | $553m | $1413m |
| | (497-809) | (160-260) | (390-713) | (1047-1781) |

Confidence intervals are indicated in brackets.

**TABLE 4** Potential cost savings from reducing preterm births, 5, 10 and 25% reduction scenarios, $m

| Metric | Extremely preterm | Moderately preterm | Late preterm | Total |
|---|---|---|---|---|
| 5% reduction | | | | |
| Birth reductions, *n* | 138 | 115 | 1087 | 1341 |
| Cost savings, $m | $33m | $10m | $28m | $71m |
| | (25-40) | (8-13) | (20-36) | (52-89) |
| 10% reduction | | | | |
| Birth reductions, *n* | 277 | 230 | 2174 | 2681 |
| Cost savings, $m | $65m | $21m | $55m | $141m |
| | (50-81) | (16-26) | (39-71) | (105-178) |
| 25% reduction | | | | |
| Birth reductions, *n* | 692 | 576 | 5436 | 6704 |
| Cost savings, $m | $163m | $52m | $138m | $353m |
| | (124-202) | (40-65) | (98-178) | (262-445) |

Confidence intervals are indicated in brackets.

very preterm birth was $89 709 and for late preterm birth was $25 417. Calculation of the total national cost for each gestational age group showed the extremely preterm group still produced the highest national cost burden, despite the numbers born at these gestational ages being the smallest. The next greatest cost was in the late preterm group due to the much larger numbers in this category.

Our study used a model developed by Mangham and colleagues to determine the cost of preterm birth in England and Wales in 2009.[5] Based on their hypothetical cohort of 669 601 children born in 2006, the total additional cost to the public sector was estimated to be £2.946 billion. Mangham and colleagues' model was also adapted to estimate the economic burden of preterm birth in Canada over the first ten years of life for infants born in 1996–1997.[6] The estimated total cost for all preterm births was $CAN587.1 million. In the USA in 2005, the Institute of Medicine estimated the societal cost of preterm birth to the nation each year was $26 billion.[7] This estimate only included costs up to five years of age. But there are implications to the economy that extend beyond just identifiable expenditures. An analysis from Hamilton County, Ohio, USA in 2012, estimated that the 1444 preterm infants cost about $93 million, but the consequences for adults born preterm amounted to 9000 fewer college degrees and $300 million in lost earnings.[26] It was estimated that prolonging each preterm birth by one week could potentially reduce medical expenditures by more than $25 million.

In the present study, the major contributor to incremental costs was neonatal intensive care, contributing about two-thirds of the cost difference. One-quarter came from additional costs of schooling. The most significant burden of neonatal costs per child comes from those born at the earliest gestational ages who also face greater rates of ongoing disability. However, the effects of preterm birth on subsequent educational needs extends across the gestational age spectrum and includes early term births. By linking school census data to birth outcomes in Scotland, the odds ratios of special educational needs increased progressively across the whole gestational-age-at-birth spectrum from 24 weeks to term.[25] Overall, gestational age at birth accounted for 10% of the adjusted population attributable fraction of special educational needs. A population-based study in New South Wales of 153 000 children of school age born from 32 weeks gestational age, showed increased risks of developmental delay with earlier birth, including language, cognitive and motor skills.[27] A similar reduction in academic achievement at school age has been demonstrated for early term births in a large study in New York, USA.[3] Studies of these types consistently show poorer educational achievement in children born preterm or early term.

It should no longer be assumed that the high costs of preterm birth are an inevitable consequence of our reproduction. There are many pathways to untimely early birth and some are now amenable to prevention. In 2014, a whole-of-population multifaceted program was introduced across Western Australia to safely lower the rate of preterm birth. In the first full calendar year, the statewide rate of preterm birth was reduced by 7.6% and in the sole tertiary level perinatal centre by 20%.[4] Over the following two years the 20% reduction in the tertiary centre was maintained, but the effect dissipated in the secondary centres where the educational program had not been sustained. These results indicate that the rate of preterm birth can be safely reduced but the benefit depends on ongoing education across the various sites.

The benefits of preterm birth prevention include fewer children with behavioural and learning problems, including need for special education assistance.[27,28] In our study, additional costs at school were calculated to contribute 25% of the incremental cost of preterm birth. Promotion of programs to safely prevent preterm birth needs to include the educational advantages at school, as well as the profound benefits for families that arise from avoidance of behavioural problems.

A weakness of this study has been our inability to estimate costs past 18 years of age. While some relevant data are accessible, there were deficiencies limiting our confidence in their completeness. The potential ongoing consequences of preterm and early term birth are now being recognised. In a study of more than 4 million livebirths in Sweden from 1973 to 2015, it was observed that low gestational age at birth was followed by increased mortality from infancy through to mid-adulthood.[29] Accurate consequences at later ages are not yet known as neonatal intensive care only came of age in the 1960s and 1970s. Nevertheless, follow-up of nearly 9000 men and women in the Helsinki Birth Cohort born between 1934 and 1944 demonstrated considerable ongoing socioeconomic disadvantages associated with late preterm birth.[30] It would be reasonable to conclude that the costs to government of preterm birth estimated in the current study up to the age of 18 years represent only a fraction of the eventual overall burden to individuals, families and the nation.

In conclusion, our study shows that the annual cost of preterm birth to the Australian government in the first 18 years of life is approximately $1.4 billion. Two-thirds of the costs are from neonatal care, and one-quarter arises from the need for special educational assistance. Our results also show that cost savings of $71 million and $141 million per year may be achieved by reducing the national rate of preterm birth nationally by only 5 and 10% respectively (Table 4). Prevention of a reasonable proportion of untimely preterm births is now possible, and these data need to be applied when decisions are made to allocate resources to prevention and treatment interventions. Further analyses will be required as the ongoing costs across the public sector and to individuals in adulthood are likely to reveal significant longer-term economic consequences.

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## SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of the article.

Supplementary Material

Appendix S1

**Table A1**. Parameters, probabilities and relative risks of events are shown for the decision-analytic model stratified by gestational age at birth (extremely, moderately and late preterm, and term birth). National probabilities are presented. The state-specific probabilities that were implemented into the model are shown in Table A2.

**Table A2**. Australian states in 2016: number of births, rate of preterm birth and mortality stratified by gestational age at birth.

**Table A3**. National costs in AUD$ implemented in the decision-analytic model. Costs are shown according to the gestational age at delivery: extremely, moderately and late preterm births and term births. All costs were modelled using the lognormal distribution.

**Table A4**. Average costs modelled by state ($AUD): delivery costs, neonatal admissions and admission beyond neonatal discharge up to 18 years of age.

**Table A5**. Overall cost burden of preterm birth by state and territory, by cost group, $AUD per birth.