ANU COLLEGE OF BUSINESS & ECONOMICS

Maternal health system costs of adverse birth outcomes

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Statement of originality

This thesis contains no material that has been accepted for the award of any other degree or diploma in any university or other tertiary institution and, to the best of my knowledge and belief, contains no material previously published or written by another person, except where due reference has been made in the text. I give consent to the final version of my thesis being made available worldwide when deposited in the University's Digital Repository, subject to the provisions of the Copyright Act 1968.

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Florence Nightingale captures my PhD research with her quote: "to understand God's thoughts, we must study statistics for these are the measures of His purpose". I am thankful to God and all the people He has put in my life to enable me to do just this.

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Lastly, this thesis tells the stories of mothers and their babies and the complexities of caring for them during a vulnerable time in their lives. It is fitting therefore, that I dedicate it to the people in my life who matter most and truly understand this difficult walk – my mum and our precious babies.

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Abstract

Adverse birth outcomes can have an overwhelmingly negative impact on many aspects of society – the infant, mother and family are intimately affected, but there are also major consequences on the overall health system. For the purpose of this study, adverse birth outcomes were defined as: premature birth, low birth weight, congenital conditions, stillbirth and neonatal death. The few studies, based overseas, that have investigated the health system costs of women following adverse birth outcomes showed these costs were significant and needed to be addressed. To date, no such studies have been conducted with Australian data.

This thesis contributes to this area by quantifying the difference in maternal health system costs of women who experienced adverse birth outcomes and those that did not, using Australian data. The cost differentials were assessed across both hospital and out-of-hospital systems. In addition, statistical and actuarial techniques were employed on a comprehensive dataset – with linkages between various administrative data and longitudinal data collected on a large, broadly representative, sample of women. The techniques adopted in this study enabled an in-depth analysis of the complexities in the area, in particular the associations between risk factors and their impact on health system costs. These results were used to develop cost-effective health policy recommendations.

The results showed that the mean maternal health system cost differentials for adverse births were substantial at 23% and 27% for hospital and out-of-hospital costs, respectively. These amounts are broadly in line with the existing literature. The key cost risk factors were mode of delivery, use of In Vitro Fertilisation treatments, specialist and general practitioner use for perinatal services, private

health insurance status, adverse births, area of residence, diabetes, smoking status and mental health factors.

The findings of this project showed that there were a number of key areas where health resources may be directed and smoking and mental health policy were considered further. With regard to smoking, programs providing incentives for smokers to quit during pregnancy have been found to produce successful outcomes and recommended for further consideration. For mental health, numerous mental health initiatives were recommended as a priority for attention. These included a national universal mental health screening protocol for antenatal and postnatal periods in conjunction with improved screening methods and health services that focus on holistic, proactive early intervention so that mental health problems are detected and treated early. While these recommendations are likely to require increased funding in some areas, the results of this study suggest they are worth exploring further as investing in preventative strategies are likely to reduce costs in the future when these women experience major life events such as the birth of a baby. Not only are the initiatives likely to be cost-effective, but more importantly, they are likely to improve the health outcomes for those women who are most at risk of experiencing these adverse conditions.

1 Introduction

Every year, thousands of Australian women endure difficult pregnancies, traumatic deliveries and complicated postnatal recoveries and, in many cases, these events correspond to these women experiencing adverse birth outcomes. The impacts of these events are often overwhelming for the women and children involved, and the consequences are far-reaching in terms of their impacts on families, wider society and the overall health system. Furthermore, the magnitude of this problem is worsening with the rates of adverse birth outcomes on the rise in many countries and there is little understanding as to why this is the case (Howson, Kinney, & Lawn, 2012; Measey et al., 2007; O'Leary, Bower, Knuiman, & Stanley, 2007). In Australia, the impact on the health system, particularly in terms of maternal health system costs, is unknown.

This thesis contributes to this area by quantifying the difference in maternal health system costs of women who experienced adverse birth outcomes and those that did not, using Australian data. The cost differentials were assessed across both hospital and out-of-hospital systems. In addition, statistical and actuarial techniques were employed on a comprehensive dataset – with linkages between various administrative data and longitudinal data collected on a large, broadly representative, sample of women. The techniques adopted in this study enabled an in-depth analysis of the complexities in the area, in particular the associations between risk factors and their impact on health system costs. These results were used to develop cost-effective policy in this area to help women through these difficult circumstances.

For the purpose of this study, adverse birth outcomes were defined as premature birth, low birthweight, congenital conditions, stillbirth and neonatal death. The latest Australian figures show that the rate of premature births, low birthweight and perinatal deaths (stillbirths and neonatal deaths combined) are 9%, 6% and 1%, respectively (Hilder, Zhichao, Parker, Jahan, & Chambers, 2014). A number of biologically-based studies investigating these outcomes found that the rate of stillbirths in Australia has remained relatively unchanged over the last twenty years, while only small improvements have been made in reducing the rate of low birthweight and premature births (Measey et al., 2007; O'Leary et al., 2007). These trends are not only observed in Australia, but the World Health Organisation finds that premature births are on the rise in most countries and reflect the leading cause of death for newborns, accounting for 35% of all neonatal deaths (Howson et al., 2012).

There is a lack of research in the area of maternal health system costs of women who experience adverse birth outcomes. The few studies that have investigated these costs suggest that the costs are significant and need to be addressed (Chollet, Newman, & Sumner, 1996; Gilbert, Nesbitt, & Danielsen, 2003; Gold, Sen, & Xu, 2013; Mistry, Heazell, Vincent, & Roberts, 2013; Petrou & Khan, 2012; Ringborg, Berg, Norman, Westgren, & Jonsson, 2006). To date, however, no such studies have been conducted with Australian data. With a better understanding of the expenditure and cost drivers in this area, more cost effective evidence-informed policy can help direct resources where needed the most.

1.1 Background of maternal health system in Australia

1.1.1 Structure and funding of maternal health system

The maternal health care system, like many other parts of the Australian health care system is a mixed public and private system. The funding is a combination of Commonwealth, State and Territory Government and privately-funded and delivered services (Bryant, 2008). Medicare is a Commonwealth Government funded scheme for health care services in Australia. It is the main source of funding of primary health care in Australia for Australian residents and certain categories of visitors to Australia (Medicare Australia, 2015). The major elements of Medicare are described in the Health Insurance Act 1973, as amended, and include free treatment for public patients in public hospitals, the payment of benefits or rebates for professional health services listed on the Medicare Benefits Schedule (MBS), and subsidisation of the costs of a wide range of prescription medicines under the Pharmaceutical Benefits Scheme (PBS). Medicare benefits are claimable only for 'clinically relevant' services provided by eligible health practitioners. A 'clinically relevant' service is one which is generally accepted by the relevant profession as necessary for the appropriate treatment of the patient. When a service is not clinically relevant, the fee and payment arrangements are a private matter between the practitioner and the patient (Medicare Australia, 2015). More details of the Medicare services are covered in Section 3.4.1.1.

Maternity services in Australia are provided by a number of different practitioners and in multiple settings leading to a range of different health care providers involved during the course of a pregnancy. Whether the patient chooses to elect private or public will also have an impact on the practitioners available to them. The maternity

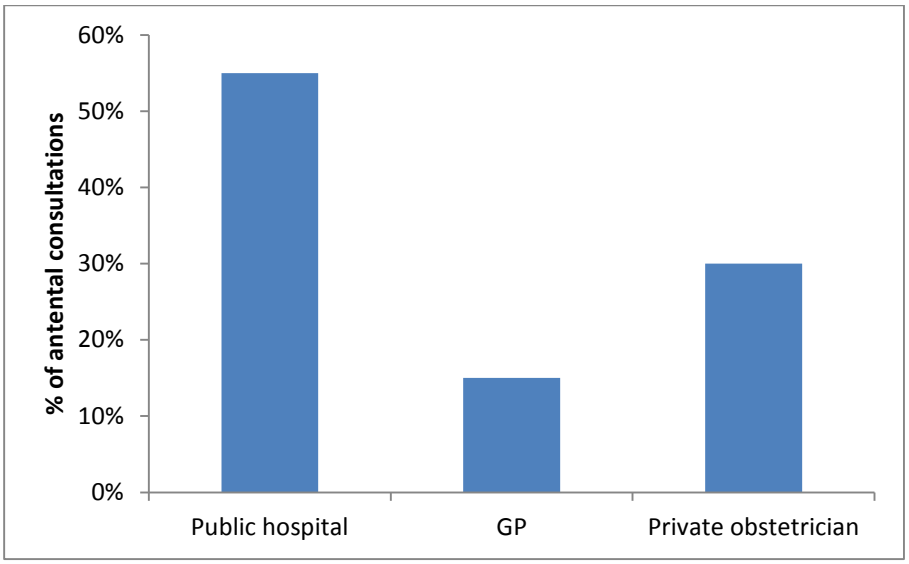
services available under both public and private systems are discussed in more detail by each perinatal period below.

1.1.1.1 Antenatal Period

Antenatal services are funded both publicly and privately. They can be provided through private antenatal consultations with private practitioners (such as obstetricians, general practitioners and midwives). In Australia, general practitioners (GP's) are also known as the family doctor and a referral from a GP is required to see a specialist such as an obstetrician. Antenatal services are government-subsidised through Medicare rebates, although these rebates are unlikely to cover the full cost, so the patient often faces out-of-pocket expenses. These services are also provided through the public system via out-of-hospital clinics in public hospitals. The latest available data suggest that there were around 3.2 million antenatal services in 2005/06, equivalent to about 12 per pregnancy. Just over half of these antenatal services were provided by out-of-hospital clinics in public hospitals and Figure 1.1 shows the distribution of antenatal services by provider in Australia in 2005/06 (Bryant, 2008)[1]:

[1] Figures obtained from The BEACH program 2000-08. Data supplied by the Australian GP Statistics and Classification Centre, University of Sydney, June 2008. Department of Health and Ageing analysis using Medicare statistics and AIHW hospital statistics.

Figure 1.1: Provision of antenatal services in Australia (2005/06)



1.1.1.2 Delivery period

In Australia, almost all births occur in hospitals and in 2012 96.9% of births occurred in hospital (Hilder et al., 2014). The alternatives in Australia are birth centres which represented 2.3% of births, planned homebirths which represented 0.4% of all births and "other" births (such as unexpected deliveries before arrival at the hospital) which made up the remaining 0.4% in 2012. Further, the majority of women giving birth in hospitals do so as public patients in public hospitals and Table 1.1 gives relevant figures for 2012 for Australia for hospital births only (Hilder et al., 2014).

Table 1.1: Hospital sector and patient election status (Australia) 2012

Australia	Type of hospital		Patient election status	
	Number	%	Number	%
Private	86,424	29.0	93,450	31.4
Public	211,563	71.0	199,836	67.1
Not stated			4,701	1.6

In terms of the funding arrangements for these patients, if the patient elects to be treated as a private patient and has private health insurance, the insurance arrangements are likely to cover some or all of the accommodation and labour costs of the birth. If the patient does not have private health insurance and elects to be treated as a private patient, they will pay these costs out-of-pocket. Medicare helps to subsidise the costs for private patients.

Public hospital services are provided free to all public patients, and they are jointly funded by State and Territory Governments and through Commonwealth funding. Some public hospitals offer birthing centres which offer midwifery-led models of care, an option not generally available in private hospitals.

While midwifery services offered through hospitals are covered under the usual funding arrangements described above, there is an important limitation where a woman chooses to deliver her baby outside a hospital (for example, at home or elsewhere). As there is no Medicare benefit payable for the management of labour and delivery from midwives, support for midwifery services through private health insurance is limited for cases such as these. The insurer may pay a benefit for the services of a midwife to manage the delivery; however, payment of such a benefit is

uncommon, and for the majority of these cases the woman would need to pay for the full cost of the midwifery services out-of-pocket. As described earlier these cases represent a very small proportion of total births (0.4% in 2012; (Hilder et al., 2014)) so are unlikely to have a material impact on the analysis.

1.1.1.3 Postnatal period

Postnatal services are predominantly funded by the States and Territories through the public system, but there is also scope for these services to be privately funded too. This is because private hospitals generally do not provide postnatal care beyond the delivery and the days immediately following. However, a woman will usually see her GP or private obstetrician for a standard follow up appointment six weeks after the birth of a baby, and these services are subsidised under Medicare. A woman may choose to consult a midwife privately for postnatal care, but there is no Medicare benefit payable for this care. Some private health insurers pay benefits from general treatment cover, otherwise the woman must pay for this care herself (Bryant, 2008).

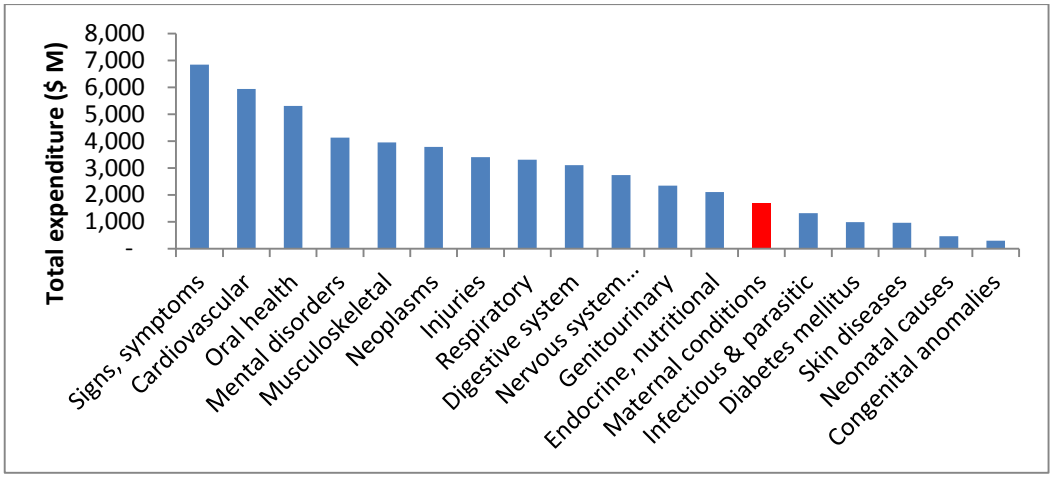
1.1.2 Health expenditure on maternity services

$1.7B was spent on maternity services in total in 2004/2005 (Australian Institute of Health and Welfare, 2008), accounting for approximately 2% of total health expenditure that year. This figure increased to approximately $2.5B in 2008/09 (Australian Institute of Health and Welfare, 2014a) and represented a similar proportion of total health expenditure in that year too. This includes expenditure

funded by government, by non-government organisations such as private health insurance funds, and by individuals through out-of-pocket expenses[2].

Figure 1.2 shows where maternity services rank in terms of total government health expenditure for which the AIHW was able to attribute the cost to a "disease" (the attribution to a disease accounted for 65% of the total government health expenditure as the remainder was unable to be attributed to any particular disease, (Australian Institute of Health and Welfare, 2010)).

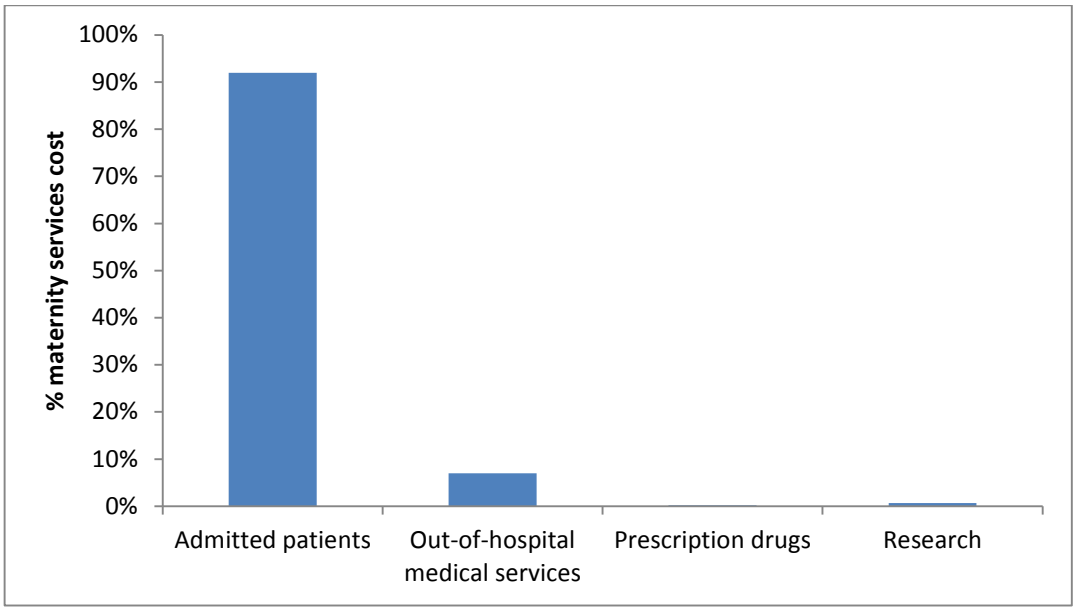
Figure 1.2: Cost of disease (maternal conditions) (2004/05)



Maternal health service costs were split into four broad categories: hospital, out-of-hospital, prescription drugs, and research. The most recent figures (in Australia) that reported on expenditure of maternity services showed that hospital and out-of-hospital costs accounted for 99% of the total government health expenditure on maternity services and the breakdown is shown in Figure 1.3 (Australian Institute of Health and Welfare, 2010).

[2] Note that this thesis considers costs from the perspective of the government, but figures were not available for solely this source.

Figure 1.3: Sources of maternal costs (2004/05)



As shown in Figure 1.3, hospital costs constituted the vast majority of the costs, contributing 92% of the overall cost, and these costs were predominantly incurred as an admitted patient during the delivery period in hospital (Australian Institute of Health and Welfare, 2010). The sources of out-of-hospital costs relating to maternity services are more complex due to the structure of maternity care in Australia. The out-of-hospital costs generally relate to antenatal and postnatal care. As described above, antenatal and postnatal care can be provided by a GP, specialist (obstetrician) or midwife. Antenatal services are also provided through the public system via out-of-hospital clinics in public hospitals. While hospital costs were clearly the largest source of expense in this area, out-of-hospital expenditure still amounted to $116M in 2004/05. These data relate to all maternity services. It is also worth noting that while the costs of maternity services may be modest compared to costs associated with other diseases, childbirth accounts for 7% of all overnight acute separations in Australian hospitals and is the most common group. Furthermore 6% of all hospital separations relate to antenatal, delivery and postnatal periods and this figure

increases to 10% if neonatal and female reproductive issues are included (Australian Institute of Health and Welfare, 2012b).

1.2 Adverse birth outcomes

The latest national figures show that the rate of premature births, low birthweight and perinatal deaths (stillbirths and neonatal deaths combined) were 9%, 6% and 1%, respectively (Hilder et al., 2014) in 2012.

Figure 1.4 shows the latest trends in these rates for NSW[3].

Figure 1.4: Rates of adverse births in NSW (1994-2014)

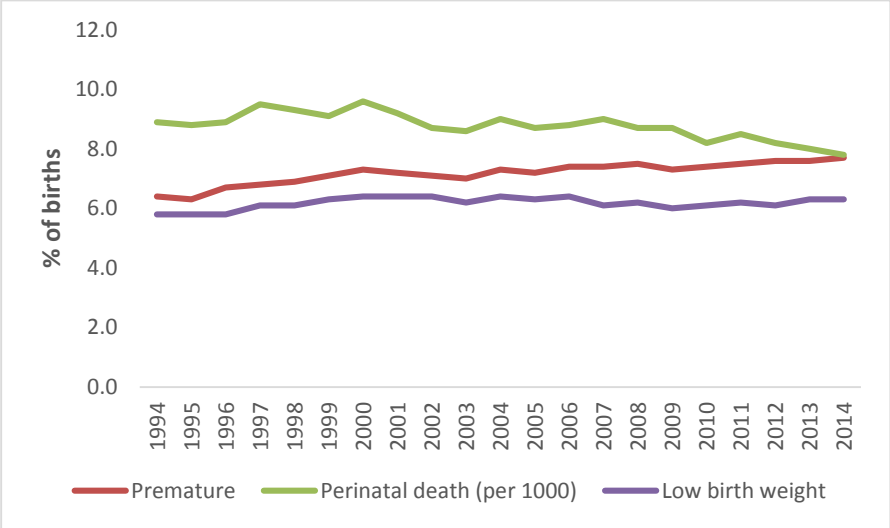


Figure 1.4 shows that the rates of low birthweight have been slowly but steadily increasing over the last twenty years; although, have stayed relatively stable in recent years. Also the rates of premature births have been increasing at a slightly higher rate across this time period (increasing at approximately 1% p.a.), while rates of perinatal

[3] Data obtained from the Perinatal Data Collection: http://www.healthstats.nsw.gov.au/

deaths have been decreasing over this time period. However, if perinatal deaths are split into their two components, the decreasing trend is a result of decreases in neonatal deaths, whilst stillbirths have stayed relatively stable in NSW over the last twenty years (at a rate of approximately 0.6% of births) as seen in other literature from different areas (Measey et al., 2007; O'Leary et al., 2007). While beyond the scope of this thesis, there is still research needed to understand the underlying causes of adverse birth outcomes which drive these trends (Howson et al., 2012). However, there has been considerable research studying risk factors of adverse births, and this literature will be reviewed in the next chapter.

1.3 Aims

As described above, there has been little research on the health system costs of women following adverse birth outcomes. This thesis quantifies these maternal health system costs with the view to informing cost-effective policy to target the women who are most at risk. Therefore, the aims of this thesis are threefold; to:

1. Quantify the difference in maternal health system costs between women who experience adverse birth outcomes with those that do not; this difference in cost will be referred to as “cost differentials”;
2. Identify risk factors that drive the maternal health system costs; these risk factors will be referred to as “cost risk factors”;
3. Use these cost differentials and cost risk factors to make recommendations for health policy so that resources can be targeted to those most at risk in a cost-effective manner.

1.4 Definitions

1.4.1 Maternal health system costs

For the purpose of this thesis, maternal health system costs were defined as:

- Hospital costs (or admitted patient costs)[4]; and
- Out-of-hospital costs (or outpatient costs).

These costs were studied in two separate but related costing studies. The costs were considered from the *perspective of the government* – so specifically focused on how much the government spent in these two areas; however, private hospitals, which are funded by both public and private sources, will also be considered under hospital costs. In order to focus the hospital costing study on public costs only, the data is split by patient status (public and private patient) to enable a better understanding of the public costs. Note that private hospital patients are also entitled to subsidies (or "rebates") from the government. These rebates are considered in the out-of-hospital costing study as the rebates are delivered through Medicare, which also covers out-of-hospital costs (see Section 1.1.1 for more details on Medicare in Australia). Finally, considering costs from the perspective of government specifically excludes all other costs (for example, out-of-pocket costs incurred by individuals and private health insurance costs).

In this context, the term "maternal" refers to the fact that this study only examined costs associated with the woman (infant costs were excluded) and, also examined costs during the complete perinatal period, defined here to be from the start of

[4] Hospital costs are often referred to in the literature as inpatient costs.

pregnancy through to the postnatal period. For the purpose of this study, the perinatal period was split into three sub-periods:

1. Antenatal period (the pregnancy period);
2. Delivery period (the labour and delivery period);
3. Postnatal period (covers up to one year following the birth of the baby, but the study also considered shorter timeframes where appropriate).

1.4.2 Adverse birth outcomes

For the purpose of this thesis, a birth is defined as "the complete expulsion or extraction from its mother of a baby of at least 20 weeks gestation or weighing at least 400 grams at birth whether born alive or stillborn." This definition is consistent with the definition used by the Australian Institute of Health and Welfare[5] (AIHW) for data collection (Hilder et al., 2014).

Table 1.2 defines the five categories of adverse birth outcomes that will be used for this thesis.

[5] The AIHW is Australia's national agency for health and welfare statistics and information

Table 1.2: Definition of adverse births

Adverse birth	Definition
Premature birth	Birth before 37 weeks gestation
Stillbirth	Fetal loss at 20 or more weeks gestation or a birthweight of 400 grams or more
Low birthweight	Birthweight less than 2500 grams
Neonatal death[6]	Death within the first 28 days of life
Congenital conditions	Child listed on the Congenital Conditions Registry (CCR). There are three types of conditions reported to the CCR: • Conditions that affect the growth, development and health of the baby that are present before birth, such as cleft lip, dislocated hip and problems with the development of the heart, lungs or other organs; • Conditions due to changes in the number of the baby's chromosomes, such as Down Syndrome; • Four conditions due to changes in the baby's inherited genetic information: cystic fibrosis, phenylketonuria, congenital hypothyroidism and thalassemia major.

Maternal health system costs and adverse birth outcomes will be considered in more detail in the following sections as they underpin the major components of this research.

1.5 Thesis outline

Chapter 2 reviews key previous literature on the maternal health system costs of adverse birth outcomes. Relevant papers are reviewed in terms of the statistical

[6] Perinatal deaths include both neonatal deaths and stillbirths.

methodology employed and the maternal health system cost results. Also reviewed is the literature on the risk factors of adverse birth outcomes in order to provide more information on possible cost risk factors and greater understanding of the drivers of adverse births.

Chapter 3 details the research methods used throughout this thesis. It begins with an introduction to the Australian Longitudinal Study on Women's Health (ALSWH) and a description of its strengths and limitations. Data and statistical methods employed in the two separate costing studies (hospital costing and out-of-hospital costing) are then discussed.

Chapter 4 and Chapter 5 consider the results of the hospital costing study and the out-of-hospital costing study, respectively. Finally, Chapter 6 combines the findings of the entire thesis, in particular the results of the cost risk factors and cost differentials from Chapter 4 and 5 to discuss possible policy options in this area, to enable a more cost-effective allocation of resources to women most at risk.

2 Literature Review

As described in the previous chapter, the two major components of this research are maternal health system costs and adverse birth outcomes. Therefore, this literature review focuses on research that covers maternal health system costing studies with specific consideration of adverse birth outcomes. Details of the literature search and findings from relevant papers are discussed, followed by a section which considers additional risk factors and their potential impacts on the maternal health system cost.

2.1 Literature search

A review of current literature showed a paucity of research in the area of maternal health system costs for adverse birth outcomes internationally, and there were no relevant publications about the Australian experience. A detailed review paper by Petrou & Khan (2012) used the following search criteria and databases in their literature review of relevant costing studies of premature births and low birthweight:

Databases searched: MEDLINE, CINAHL, EconLit, Science Citation Index (SCI), Social Science Citation Index, Index to Scientific and Technical Proceedings (ISTP), British Library Inside Information (BLII), EMBASE, Cochrane Library (CDSR), York Database of Abstracts of Reviews of Effectiveness (DARE), National Health Service (NHS) Economic Evaluation Database (NEED) and the Database of Consortium of University Research Libraries (COPAC).

Search terms used were as follows: minor and major topics covered by MeSH terms for ‘preterm birth’, ‘prematurity’ and ‘low birthweight’ combined with ‘cost’, ‘economic’, ‘financial’ and ‘burden’.

The results of these searches revealed twenty relevant papers but only three covered both the costs of initial hospitalisations and costs following initial discharge. None of the papers involved Australian data. The focus of these studies was on the *infant* costs rather than the *maternal* costs, although four of these studies (Chollet et al., 1996; Gilbert et al., 2003; Luke, Bigger, Leurgans, & Sietsema, 1996; Ringborg et al., 2006) also reported on the mean per patient maternal cost.

The Petrou & Khan (2012) search method was used as a starting point for the current literature search but with some key modifications to focus principally on maternal costs. The first modification was to add the term 'maternal' (which also captured 'mother') as an All Fields search term (as 'maternal' is not a MeSH term) to the search strategy used by Petrou & Khan (2012). 'Women's health' and 'women's health service' were also considered as MeSH terms. The terms associated with the birth outcomes in Petrou & Khan's search were also augmented with other outcomes for the current study ('stillbirths', 'neonatal deaths', 'perinatal deaths', 'congenital conditions' and 'congenital abnormalities'). This expanded search yielded two more relevant papers, both published after Petrou & Khan's literature review, and both related to the cost of stillbirths (Gold et al., 2013; Mistry et al., 2013). Note, however, that although there may be other publications focussed on the infant cost of adverse birth outcomes, this feature was out of scope for this thesis. This search was conducted annually and updated over the whole research period of this thesis (2012-2016).

2.2 Previous research results

Four papers have reported that the mean maternal per patient (admitted patient) cost of a premature birth is significantly greater than that for a full-term birth, particularly

for very premature births (Chollet et al., 1996; Gilbert et al., 2003; Luke et al., 1996; Ringborg et al., 2006). Chollet et al. (1996), found that even births that occur just before full term have a mean maternal per patient cost substantially more (over 50%) than a full-term birth, and both Gilbert et al. (2003) and Luke et al. (1996) found the cost multiplier to be more than double for very premature births. Gold et al. (2013) also found the mean maternal hospital costs of stillbirths to be significantly higher than for live births.

2.2.1 Gold et al. (2013) and Mistry et al. (2013)

The two most relevant papers in the subject area were those by Gold et al. (2013) and Mistry et al. (2013). Both papers focussed on the hospital costs of stillbirths. Gold et al. (2013) started the study by undertaking a retrospective review of patients' records across three hospitals in the US over the period 1996-2006 (however, not all stillbirths were included due to inadequacies in the hospitals' data recording processes). This gave them a final sample of 1053 live-birth controls matched to 533 stillbirths matched by hospital of delivery, maternal age, and year of delivery, so these variables did not differ significantly between the groups. The authors considered hospital costs related to the labour and delivery phase only. They found the hospital cost distribution to be close to normally distributed and performed a linear regression analysis on stillbirth hospital costs with significance level set at 5%. Seven binary variables were used as covariates in their model: first pregnancy; no prenatal care; anaesthesia; late stillbirth (that is, after 28 weeks); caesarean delivery; induction of labour; and serious medical complication. Only the last covariate, serious medical complication, was found to be significant. The authors also fit another multivariate regression model for the cost differentials, and found that women who experienced stillbirths had a significantly higher average hospital cost

compared to women who had live births (even when multiple births and serious medical complications were excluded), but none of the covariates appeared to have a significant effect on the difference in costs. The authors found the mean hospital cost for a stillbirth was $USD 7,495 (Range: $USD 659-$USD 77,080) compared to $USD 6,600 for live births (Range: $USD 269-$USD 64,010). All cost estimates were expressed in 2010 USD using the medical care component of the Consumer Price Index for all urban consumers. Finally, the authors recommended further research examining the economic impact of stillbirths beyond labour and delivery to measure cost impacts associated with additional monitoring and care during subsequent pregnancies, to better understand the overall economic impact of stillbirths.

Mistry et al. (2013), based in the UK, addressed the further research recommendation of Gold et al. (2013). The authors started with an extensive literature review and, like Petrou et al. (2012), noted a paucity of relevant published work. The authors divided their participants into a number of categories depending on complications in their previous pregnancy; pre-existing conditions (for example, diabetes and hypertension) and previous stillbirths with known and unknown causes were grouped separately. The costs were analysed in two phases: the costs of investigation and care following a stillbirth was considered phase one, and antenatal and delivery care costs in a subsequent pregnancy was deemed phase two. The costs in the first phase were calculated by breaking down this cost into several components and using data from the University of Manchester Hospital Laboratory to value the individual components. They used a bottom-up approach to estimate the second phase due to scarcity of data for direct estimation; their estimation of delivery costs was based on pre-conception care costs, the total number of antenatal attendances,

ultrasound scans and probabilities for different modes of delivery. They found the cost in the first phase could be as high as 1,804 GBP. For the second phase, the cost varied from 2,147 GBP for those deemed to be in the lower risk category to 3,870 GBP for those deemed higher risk. Costs were expressed in 2010 GBP terms. There were no comparisons to women who did not experience stillbirths; rather, the comparisons were between the groups of women who had experienced previous stillbirths. The authors extended their financial estimates to predict the associated cost burden faced by the national health care system in the UK as 16.7M GBP. They concluded that stillbirth placed a significant financial burden on the UK health system.

2.2.2 Ringborg et al. (2006)

The Swedish study by Ringborg et al. (2006) attempted to quantify admitted costs and lengths of hospital stays for premature births in Sweden. Their aims were to provide estimates of the first year lengths of stay and admitted patient costs of infants admitted for neonatal care by week of gestation and by birthweight; and the length of stay and admitted costs of delivering women during the ante- and postnatal period by week of gestation and birthweight of the infant.

The data used in their study were all singleton deliveries between 1998 and 2001 (a total of 336,136 infants) sourced from the Medical Birth Register provided by the Swedish National Board of Health and Welfare. The premature birth rate for these data was 5%, where the definition for premature births was birth before 37 weeks gestation. The low birthweight rate was 3.1%, where the definition was less than 2500g for low birthweight. First year hospitalisations of infants admitted to neonatal care 0-6 days after birth were tracked, as were hospitalisations of women for whom

the date of admission lay between 28 days prior and 28 days after the date of delivery using the Hospital Discharge Register. Costs were assigned using NORD-DRG (diagnosis related group) classification system.

Validity of the cost estimates was analysed using two-sided t-tests of the bootstrapped means (1000 replications). Various hypothesis tests were also conducted to analyse the cost differences. These included standard one-sided t-tests as well as non-parametric bootstrap tests. Results were considered significant if p values were below 0.001.

The study found significant differences in average length of stay for both premature and low birthweight delivering women compared to women who did not experience these adverse birth outcomes. In addition to this finding, the mean maternal costs for women who had premature births were 37% higher than women who had term births, and the mean cost differential for women who had low birthweight babies was 47% higher than those that did not. The correlation between a women's length of stay and the admitted costs assigned was high. Unfortunately, the statistical testing was not conducted on the maternal costs but rather mean maternal costs were reported at different gestation ages and birthweights. These mean costs are shown graphically below. Both graphs show that there is a clear trend, with decreasing maternal costs as gestational age and birthweight increase, with the exception of very early gestation (<25 weeks) and very low birthweights (<750 grams). The cost differentials are expressed in 2001 money terms and depended on the gestation age and birthweight but varied from 20%-100%.

Figure 2.1: Mean maternal cost by gestation (Ringborg et al. 2006: Sweden, 1998-2001)

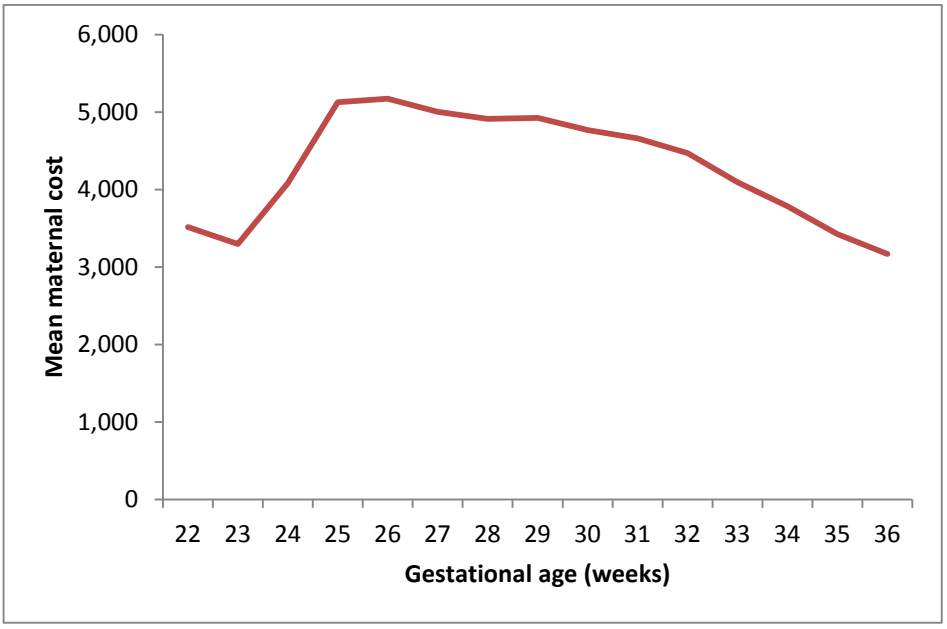
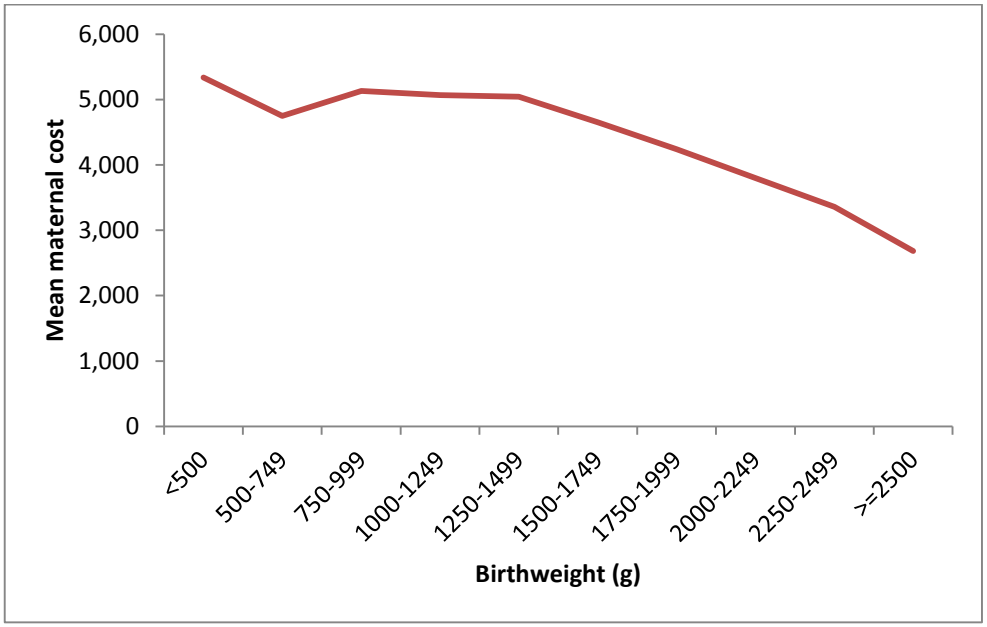


Figure 2.2: Mean maternal cost by birthweight (Ringborg et al. 2006: Sweden 1998-2001)



The authors comment on some of the limitations of using the DRG methodology for costing purposes. The DRG prices measure the charge rather than the true resource

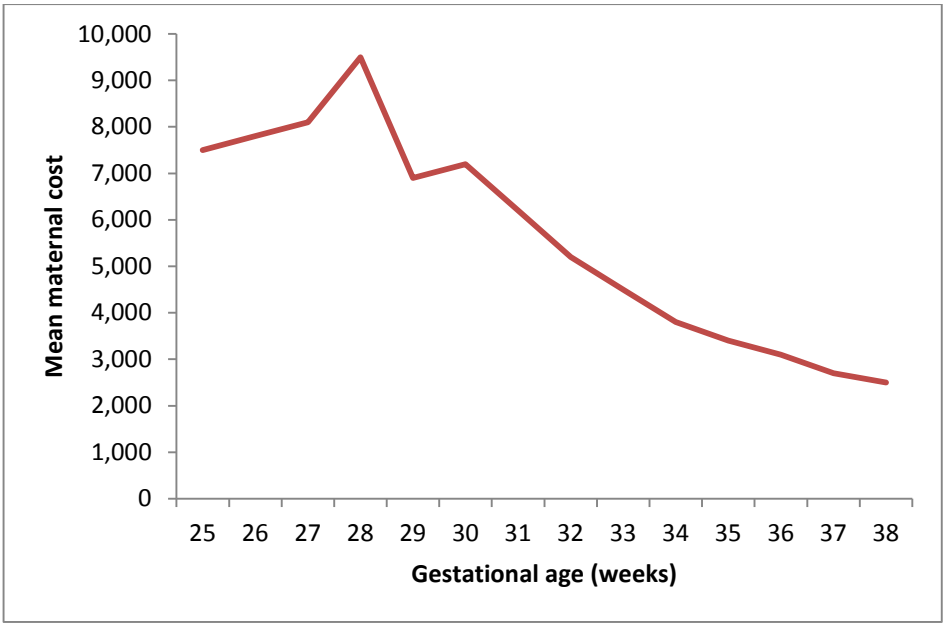
use. They stated that “though the strong correlation between the estimated length of stay and costs of care indicates that the DRG-based costs accurately reflect quantity of care between gestational-age and birthweight subgroups, it is not possible to judge whether the general level of costs for this type of care is excessively high, or possibly too low” (p1554). They also made the point that premature delivery is associated with a slight but statistically significant higher resource use among mothers in terms of length of stay as well as estimated costs.

2.2.3 Gilbert et al. (2003)

Gilbert et al. (2003) attempted to determine gestational age and birthweight related pregnancy outcomes and resource use associated with prematurity in surviving infants. Their study used a statewide database from hospitals in California (January 1, 1996 to December 31, 1996), which linked maternal and neonatal-infant hospital discharge records to vital birth record statistics. This resulted in a database of over 543,000 deliveries. Singleton deliveries only were included with gestational age measured weekly from 25 to 38 weeks and birthweight measured in 250g increments from 500 to 3000g or above. Only infants that survived the first year of life were included in the calculations for lengths of stay and costs after birth. The variables studied were: respiratory distress syndrome (RDS); use of mechanical ventilation; length of hospital stay in days; and hospital costs (all on a univariate basis). Once again, the focus of this study was on the infant costs but the authors also reported on mean maternal costs. The maternal costs included any prenatal admissions, delivery admissions and possible subsequent transfers until the woman was discharged to home.

The results by gestation and birthweight revealed similar patterns to Ringborg et al. (2006). The reported mean maternal cost per week by gestation increased steadily from 25 to a peak of 28 weeks and then decreased steadily until 38 weeks. The authors also showed that the costs in early gestational ages were only marginally greater than costs at 38 weeks gestation for maternal costs, but were significantly (almost 90-fold) greater when considering infant costs. The maternal cost differential varied from 15% to 250% for gestation depending on the extent of prematurity of the infant (the year that these costs were expressed in was not specified). Figure 2.3 shows how mean maternal cost varied by gestation age (note that the definition used for premature births in this thesis is babies born prior to 37 weeks gestation).

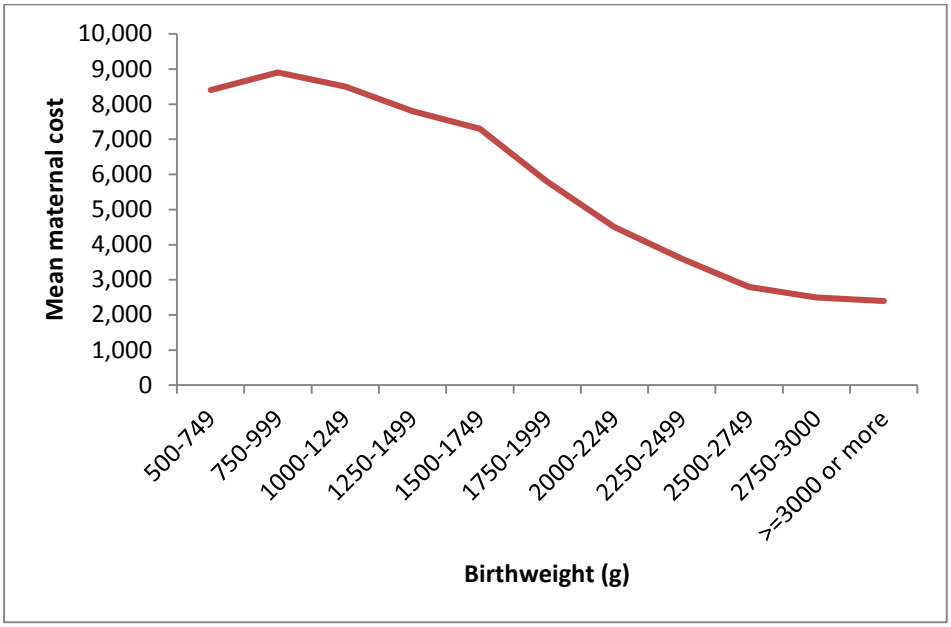
Figure 2.3: Mean maternal cost by gestation (Gilbert et al. 2003)



Similarly, when considered by birthweight, the results showed that the mean maternal cost peaked at 750-999 g and then decreased as birthweight increased (note that the definition for low birthweight in this thesis is babies born less than 2500g).

The maternal cost differential varied from 29% to 218% depending on the birthweight of the baby.

Figure 2.4: Mean maternal cost by birthweight (Gilbert et al. 2003)



2.2.4 Luke et al. (1996)

The focus of the paper by Luke et al. (1996) was on assessing the costs of prematurity for twins versus singletons, but the authors also reported on mean maternal costs. The question of how much of neonatal morbidity and associated costs were due to infants who were born as premature, twins, or premature twins was addressed using three groups of infants: twins, singletons and singletons matched to twins for gestational age. Also this study only focussed on costs associated with birth admission (delivery) because of the consistency of care provided across all gestational-age categories. In order to ensure there was consistency in how costs were measured, the three groups of infants were studied over a one-year period (July 1991 to June 1992) for a single institution based in Chicago, Illinois (USA).

Luke et al. conducted univariate analysis to compare various combinations of the three groups. The data were split into five groups of gestational age categories based on clinical relevance (25-27 weeks, 28-30 weeks, 31-34 weeks, 35-38 weeks and 39-42 weeks). They conducted various hypothesis tests depending on whether the variables were categorical or continuous – for categorical variables, chi-square tests and for continuous variables two-sided independent samples two-sample Student's t-tests (for two groups) and analysis of variance tests (for three groups) with significance at $p < 0.05$ were employed. Where the assumptions for using parametric tests were clearly violated, they used non-parametric tests including Wilcoxon's signed-rank test and the Kruskal-Wallis one-way analysis of variance (ANOVA) test.

Total maternal costs were found to be slightly higher for mothers of twins than for mothers of singletons, but costs for both groups were significantly higher when compared to mothers of premature births (as in Gilbert et al. 2003 the year in which these costs were expressed was not specified). The authors also concluded that prematurity was the predominant cost risk factor at birth for the sample, regardless of plurality.

2.2.5 Chollet et al. (1996)

The USA study by Chollet et al. (1996) used data from an employer-sponsored health plan to examine the cost and incidence of poor birth outcomes. "Poor" birth outcomes were defined in terms of DRG descriptions at the time of birth and include premature births and other infants with problems at birth. The insurance company's national book of group business was used, which covered approximately 5.5 million employees and dependents nationwide. They studied national admitted and

outpatient claims data for antenatal, delivery and postnatal care for nearly 59,000 mother-infant pairs over a two-year period (1989 to 1991), and estimated the total cost of maternal and infant care during this period (but they also did not specify what year the costs were expressed in). Furthermore, a selected cohort of 20,000 mothers and infants was examined in greater depth to compare the time pattern of maternal and infant costs for infants born prematurely or with health problems to healthy full-term infants. For most of the study these two costs were grouped together, but some results were reported separately for women and infants.

The results of this study showed that 25% of deliveries resulted in poor birth outcomes, which accounted for 40% of total costs over the two-year period and provided overwhelming evidence that these outcomes represented a significant cost to employer-sponsored health insurance plans. The authors found that the mean cost of women with premature babies was 60% higher than that for women with full-term babies, even when these babies had no other significant problems. They also found that delivery costs (for both women and infants together) represented over 60% of the total cost, while around 10% of the total cost was incurred in the antenatal period and the remainder was incurred postnatally. These breakdowns varied depending on the birth outcome; for example, with extremely premature babies, the proportion of cost incurred antenatally was significantly lower than that for full-term babies because these cases have a lot less time to receive antenatal care (however even with this limited antenatal care, the average antenatal cost for extremely premature babies was still higher than for full-term babies). Unfortunately, these cost distributions and average costs by period cannot be compared directly to the costs in this thesis as Chollet et al. (1996) included infant costs.

Furthermore, when the cost results were extrapolated nationwide the authors found this cost burden (infant and women combined) accounted for approximately 3% of aggregate after-tax corporate profits. In conclusion, the authors stated that "poor birth outcomes represented a significantly higher cost for both the mother and infant at all stages of care – prenatal, at birth, and postnatal. To the extent that poor birth outcomes relate to maternal behaviour and are preventable, their very high and protracted cost may justify substantial health promotion activity by employers and insurers" (p.1).

The authors concluded the paper with comments regarding intervention methods that could give rise to substantial savings to society and employers. On this note, a number of initiatives were proposed. Firstly, the authors recommended the introduction of substantial health promotion activity by employers and insurers targeted to avoid premature births. In particular they suggested focussing on risk factors that are well known to be related to poor birth outcomes, such as alcohol consumption, drug use, cigarette smoking, and coffee consumption during pregnancy (D. Bateman, Ng, Hansen, & Heagarty, 1993; Feldman, Minkoff, McCalla, & Salwen, 1992; Fenster, Eskenazi, Windham, & Swan, 1991; McDonald, Armstrong, & Sloan, 1992; Olsen, Pereira, & Olsen, 1991; Petitti & Coleman, 1990). Another suggestion was to modify employees' and spouses' behaviour to improve birth outcomes using employee assistance plans. They used the example of the California diabetes and pregnancy program which concluded that each dollar spent on intervention saved more than five dollars in avoided hospital costs (Scheffler, Feuchtbaum, & Phibbs, 1992). The final two suggestions were modification of conditions of employment that relate to the physical and mental conditions of employees and a better understanding of pregnancy medical management variations

and whether this had an impact on cost. The final suggestion was an area that the government should address in the interests of reducing cost and also improving health outcomes for mothers and infants.

2.2.6 Summary

All of the papers that have been reviewed focus on infant costs of adverse birth outcomes and only report on (rather than analyse) mean maternal hospital costs of adverse birth outcomes where possible, with the exception of Gold et al. 2013 and Mistry et al. 2013. Few papers considered more sophisticated costing models or the complete perinatal period across both hospital and out-of-hospital costs. A summary of the scope of the papers is shown in Table 2.1:

Table 2.1: Summary of previous research[7]

	Health system		Time period			Adverse births				
Paper	Hospital	OOH	Ante	Del	Post	Premature	Stillbirth	CC	LBW	Neo death
Gold et al. 2013	X			X			X			
Mistry et al. 2013	X	X	X	X	X		X			
Ringborg et al. 2006	X		X	X	X	X			X	
Gilbert et al. 2003	X		X	X		X			X	
Luke et al. 1996	X			X		X				
Chollet et al. 1996	X	X	X	X	X	X	X	X	X	

Mistry et al. (2013) and Chollet et al. (1996) were the only papers that considered out-of-hospital costs and the former only considered stillbirths (that is, did not actually compare these costs to women who did not experience stillbirths). Chollet et al. (1996) had the best coverage across health system costs, time periods analysed and adverse birth definitions but, unfortunately, did not split the costs by infant and mothers for most of the analysis, focussing instead on the combined costs. It is also difficult to align the definitions of adverse births used in that paper directly with the

[7] OOH, Ante, Del, Post, CC, LBW and Neo death refer to Out-of-hospital, Antenatal, Delivery, Postnatal, Low birthweight and Neonatal deaths, respectively

definitions used in this thesis but, given the way the definitions were constructed (using DRG descriptions at the time of the birth of the baby), it is likely that they excluded neonatal deaths within the first 28 days of birth as well as potentially some congenital conditions that may not have been known at the time of birth. None of the papers considered cost risk factors in depth, and only one cost risk factor (maternal complications) was identified as significant when it was considered amongst six other factors (Gold et al., 2013). Given the very limited findings on risk factors and the importance this topic has for this thesis, this aspect will be considered in more detail in the next section.

Finally, it was useful to compare the cost differentials by paper where they were available. The cost differential is defined as the ratio of the cost associated with women who had adverse births to that associated with those who did not. For the papers reviewed, the mean maternal cost was used for both cohorts of women, with indicative figures presented in Table 2.2[8]:

Table 2.2: Cost differentials in previous research

Paper	**Cost differential**
Gold et al. (2013)	10% for stillbirth
Mistry et al. (2013)	N/A
Ringborg et al. (2006)	36% for premature and 47% for low birth weight
Gilbert et al. (2003)	15-252% (mean 52%) for premature and 29-218% (mean 99%) for low birth weight
Luke et al. (1996)	72-137% for premature
Chollet et al. (1996)	60% for premature

[8] Note the ranges in Gilbert et al. (2003) and Ringborg et al. (2006) relate to the gestation and birthweight periods analysed in each study.

These results showed that the mean maternal cost differentials for many types of adverse birth outcomes were significant but there was also large variation across reported research results. There are many possible reasons for this variation, including (but not limited to) differing health systems across the countries studied, differing datasets analysed, differing methodologies for calculations and differing definitions of cost, time periods analysed and/or adverse births. Notwithstanding this issue, these results still provide a useful guide to cost differentials that may be considered for comparison purposes in the work that follows.

The major shortcoming of the previous research (with the exception of Gold et al. 2013) was the lack of sophisticated statistical analysis, which is important for two key reasons. The first is that a robust statistical analysis will provide statistical significance to the results so that more confidence can be placed on the cost impacts of adverse births. Secondly, other cost risk factors may be identified and their impacts may also be determined in a way which accounts for the correlations and interactions between all the cost risk factors together. Importantly, this also ensures the impacts of adverse births are assessed more accurately as other cost risk factors will also be taken into account. In other words, this methodology ensures adverse births are considered *in combination with and taking into account* other potential cost risk factors to test whether it is indeed the adverse births that are driving the cost, and not some other cost risk factor. Gold et al. 2013 considers these issues but for stillbirths only and with a limited number of covariates.

This thesis will contribute to this area by avoiding this shortcoming and quantifying cost differentials using Australian data for each of hospital and out-of-hospital costs. Multivariate modelling techniques will be used on a large, comprehensive dataset

that has hundreds of factors available to include as covariates in the models, and hence as potential candidates as cost risk factors. The ability to include the depth of factors available in this research enables a more complete understanding of the underlying drivers of cost and, importantly, the selection of the most significant factors, which can then be used when informing health policy. An indicator of adverse births will also be included as a covariate in the multivariate models to understand whether such events are indeed a significant driver of the cost even after taking account of the other cost risk factors.

2.3 Adverse birth risk factors

As outlined in Chollet et al. (1996), there are numerous well known risk factors of adverse birth outcomes. These authors suggested interventions that target these risk factors as it is likely that these risk factors are related to higher health system costs; however, their study did not test this proposition. This section considers this idea further by reviewing the literature on risk factors of adverse birth outcomes and concluding with some considerations of their potential cost implications. Note that one of the aims of this thesis is to understand the *cost* risk factors so the modelling phase will be able to provide further evidence into the aforementioned proposition by Chollet et al. (1996). The risk factors have been grouped into the following areas and each will be discussed in turn: demographic factors, reproductive history, health behaviours and psychological and physical wellbeing.

2.3.1 Demographic factors

Abundant past research has found demographic factors such as socioeconomic status, age, education and area of residence have been associated with adverse birth outcomes (Goy, Dodds, Rosenberg, & King, 2008; Morgen, Bjork, Andersen,

Mortensen, & Andersen, 2008; Petersen et al., 2009; Stephansson, Dickman, Johansson, & Cnattingius, 2001), as has race (Sharma, Salihu, Oyelese, Ananth, & Kirby, 2006). Research has found that women who are older and less educated are more likely to experience an adverse birth and their infant is more likely to be in need of greater neonatal care (B. T. Bateman & Simpson, 2006; Battin, Sadler, & Net, 2010; Delbaere et al., 2007; Jacobsson, Ladfors, & Milsom, 2004).

2.3.2 Reproductive history

Reproductive history has also been associated with adverse birth outcomes including premature birth, low birthweight and stillbirth. Past reproductive events such as previous premature births, stillbirths, terminations and miscarriages have been associated with subsequent premature birth (Bhattacharya, Townend, Shetty, Campbell, & Bhattacharya, 2008); (Esplin et al., 2008) previous miscarriage, low birthweight and pre-term delivery have been found to reliably predict subsequent low birthweight (Bhattacharya et al., 2008; St-Laurent et al., 2008). Additionally, previous stillbirth has been associated with subsequent stillbirth (Reddy, 2007), as has a history of premature and small-for-gestational-age births (Surkan, Stephansson, Dickman, & Cnattingius, 2004), and caesarean deliveries (Smith & Wood, 2008). Note, the definition for "small-for-gestational-age births" relate the birthweight of the baby to the gestational age, and therefore is not the same as the definition for low birth weight births (which takes no account of the gestational age of the baby).

Assisted reproductive technology (ART) has also been associated with increased risk of adverse births in numerous studies. Women who have used ART have been found more likely to have premature births (Sauber-Schatz et al., 2012), low birthweight and small-for-gestational-age babies (D'Angelo, Whitehead, Helms, Barfield, &

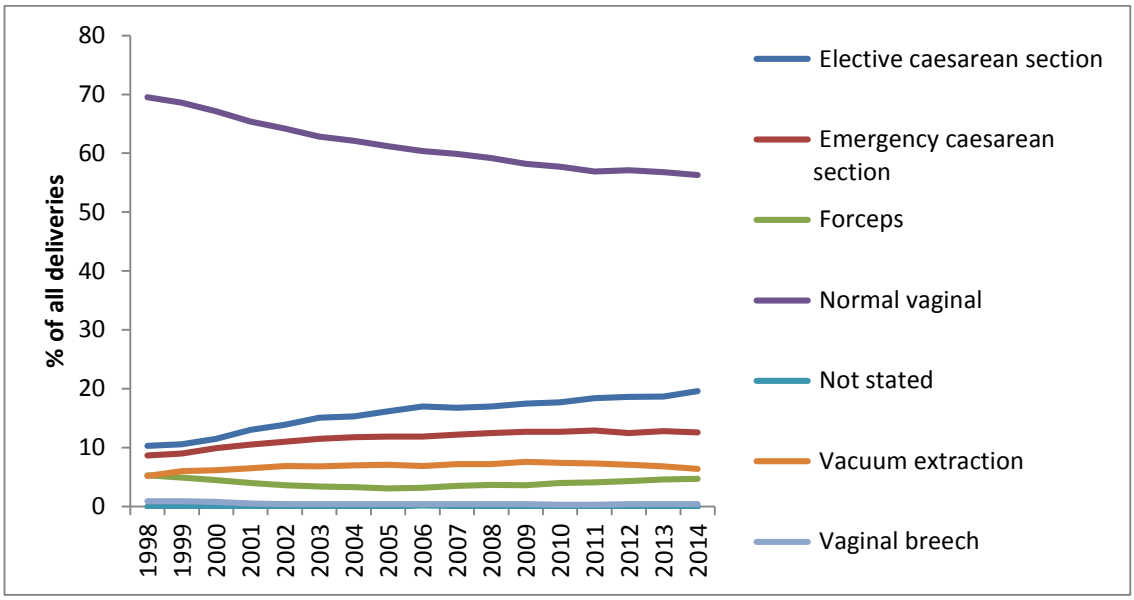
Ahluwalia, 2011). A link has also been found between early prematurity and infertility in women (as opposed to infertility in the man) who used ART (Dunietz et al., 2015). Furthermore, an increased risk of premature births and low birthweight has been found when comparing cohorts of women who receive ART to cohorts of women who were subfertile but did not receive ART; this risk was found to be even greater when these cohorts were compared to fertile women (Declercq et al., 2015).

There is also evidence to show that the rate of caesarean deliveries among women who used ART at 48.9% in 2010 (Macaldowie, Wang, Chambers, & Sullivan, 2012) was markedly higher than for the general population of women having babies which was 31.5% for the same year (Li, Zeki, Hilder, & Sullivan, 2012). The higher rate of caesarean deliveries following ART treatment may be related to the fact that women were five years older on average and more likely to experience multiple births following ART treatment (Macaldowie et al., 2012).

It is also worthwhile considering in more detail the changing landscape in maternal health care with regard to both caesarean deliveries and ART, particularly given their known high health system costs (Independent Hospital Pricing Authority, 2015; Medicare Australia, 2015). There has been a steady and substantial increase in the use of caesarean deliveries compared to vaginal deliveries in Australia in the last twenty years. In 2011, 95,894 women gave birth by caesarean delivery, which represents approximately 32% of all deliveries (Australian Institute of Health and Welfare, 2014a). Furthermore, rates of caesareans have risen from 18% in 1991 to 32% in 2011. Vaginal births (without intervention), on the other hand, have fallen from 70% to 56%. Births requiring instrumental assistance, such as forceps or vacuum extraction, have remained relatively stable between 1991 (13%) and 2011

(12%) (Australian Institute of Health and Welfare, 2014a). These trends were also observed in NSW as shown in Figure 2.5 below.

Figure 2.5: Types of delivery in NSW[9] (1998-2014)



There have been a number of reasons observed by the AIHW (2014a) for the rise in caesarean deliveries in Australia. Firstly, age is considered to be a key factor for the rises as caesarean deliveries are more common among older women. For example, in 2011 the rate of caesarean delivery was 41% among women aged 35–39 and 49% for women aged 40 and over (Australian Institute of Health and Welfare, 2014a; Hilder et al., 2014). Secondly, first time mothers are observed as having higher rates of caesarean deliveries and in 2011, 33% of first-time mothers gave birth by caesarean delivery compared to a rate of 10% for women had given birth before. Thirdly, in 2011, 84% of women with a history of caesarean delivery had a repeat caesarean

[9] Data obtained from the Perinatal Data Collection from http://www.healthstats.nsw.gov.au/

delivery, 12% gave birth without intervention and 4% gave birth with instrumental assistance so prior history of caesarean deliveries is considered to be another reason for rising caesarean deliveries. Finally, caesarean delivery rates are higher in private hospitals compared to public hospitals even after adjusting for differences in age demographics across hospital sectors. The figures showed that 40% of women in private hospitals gave birth by caesarean delivery in 2011 compared to 30% in public hospitals (Australian Institute of Health and Welfare, 2014a).

There are currently no data available on the urgency of the caesarean deliveries and the health conditions associated with the procedure – information that would be vital for understanding the risk factors of caesarean deliveries as well as for evaluating the outcomes of these deliveries. The data currently collected on the reasons for caesarean deliveries are not comprehensive or consistent across states (Hilder et al., 2014).

Accordingly, the development of national data is being pursued by the AIHW (Australian Institute of Health and Welfare, 2014a) with the states and territories for the purpose of understanding clinical indications for caesarean delivery, and this data discovery will provide a more complete picture of the maternal risk factors. Note that there is already a national perinatal data collection which is based on the PDC for all states and territories, but due to the inconsistencies in data collected regarding caesarean deliveries by state and territory the use of that national data for the purpose of understanding this issue is limited. It is also worthwhile emphasising here that caesarean delivery is a risk factor that has significant cost implications, because caesarean deliveries cost substantially more than vaginal deliveries – the current hospital cost weights show an uncomplicated caesarean delivery costs more than

double an uncomplicated vaginal delivery (Independent Hospital Pricing Authority, 2015).

In NSW the "Towards Normal Birth in NSW" Policy Directive was implemented in 2010 (NSW Ministry of Health, 2010) to address the issue of rising caesarean deliveries across both public and private hospitals. The Directive provided direction to NSW maternity services regarding actions to increase the vaginal birth rate in NSW and decrease the caesarean delivery rate by providing strategies and training to medical practitioners and care providers in order to do this. No official review of the directive was available at the time of writing. However, the trends seen in Figure 2.5 generally do not show improvements in the rates of caesarean delivery in recent years. As the reasons for caesarean deliveries are complex and not well understood, it is an area where further work has been called for (Australian Institute of Health and Welfare, 2014a) in order to meet this objective of reducing caesarean delivery rates. The success of such initiatives is likely to have a substantial impact on health system costs.

In the last twenty years, there has also been an increase in the use of ART for women who have issues with reproductive health or infertility (Australian Institute of Health and Welfare, 2012a). The latest figures in the annual report produced by the AIHW on maternal and infant health (Mothers and Babies (2012)) showed that 4% of women who gave birth in Australia used ART. Research has shown there is a relationship between ART and increased risks of adverse births (D'Angelo et al., 2011; Declercq et al., 2015; Dunietz et al., 2015; Sauber-Schatz et al., 2012); a phenomenon which could have major cost impacts. It is also likely that women who

have received ART will require more specialist or frequent monitoring during their pregnancies which could exacerbate this cost impact further.

2.3.3 Health behaviours

Several health behaviours have also been related to adverse birth outcomes, including: smoking (Flenady et al., 2011; Hogberg & Cnattingius, 2007; Odendaal, Steyn, Elliott, & Burd, 2008; Olsen et al., 1991; Wisborg, Kesmodel, Henriksen, Olsen, & Secher, 2001); alcohol use (Kesmodel, Wisborg, Olsen, Henriksen, & Secher, 2002; McDonald et al., 1992; Odendaal et al., 2008); low levels of physical activity (Frederick, Williams, Sales, Martin, & Killien, 2008); high and low body mass index (Hauger, Gibbons, Vik, & Belizan, 2008) and obesity (Chu et al., 2007; Flenady et al., 2011). Additionally, the Flenady et al. (2011) study ranked maternal overweight and obesity the highest in terms of the impact of risk factors for stillbirth. Poor pre-pregnancy and pregnancy diet (Ashdown-Lambert, 2005; Conti, Abraham, & Taylor, 1998; Fowles & Gabrielson, 2005) has also been linked with adverse birth outcomes as has medication use such as psychotropic drugs, asthma medication and anti-epilepsy drugs (Alexander, Dodds, & Armson, 1998; Artama, Auvinen, Raudaskoski, Isojarvi, & Isojarvi, 2005; Calderon-Margalit, Qiu, Ornoy, Siscovick, & Williams, 2009).

2.3.4 Psychological and physical wellbeing

Psychological and physical wellbeing have also been implicated as risk factors for adverse birth outcomes. For instance, symptoms of fatigue, stress and tiredness have been related to adverse birth outcomes (Hedegaard, 2002; Wisborg, Barklin, Hedegaard, & Henriksen, 2008), as has antenatal depression and anxiety (Alder, Fink, Bitzer, Hosli, & Holzgreve, 2007). However, little is known about

psychological history of women before pregnancy and its relationship with adverse birth outcomes.

For physical health, adverse birth outcomes have been associated with a history of existing diagnoses such as diabetes (including gestational diabetes) (Cheng et al., 2008; Flenady et al., 2011), hypertension (including gestational hypertension) (Flenady et al., 2011; Thame et al., 2000), and asthma and other breathing difficulties (Evans, Palta, Sadek, Weinstein, & Peters, 1998).

2.3.5 Cost implications

As discussed in Section 2.2, there was little previous research that directly considered maternal health system costs in relation to adverse births. Therefore, it was useful to consider how risk factors of adverse birth outcomes may impact on maternal health system costs. Each group of risk factors was considered below in relation to possible impacts on cost. Note that these factors will also be specifically tested in the modelling phase so that statistical confidence may be placed around some of the issues discussed here.

Demographic factors: Demographics factors such as income, socioeconomic status, age, education and area of residence are all likely to be cost risk factors as they are likely to have an impact on the pathway of care that a woman selects during the perinatal period. For example, women who have higher incomes are more likely to have private health insurance due to the government's punitive tax regimes if they do not purchase private health insurance. It is reasonable to suggest that women with private health insurance will use this cover to receive specialist care. While private health insurance will not cover the specialist antenatal care (which will, however, be partly covered through Medicare rebates), the woman will receive benefits from the

private health insurance when delivering her baby in hospital. Furthermore, age may also impact on the services a woman chooses as she may be more concerned about her health and pregnancy if she is older. Area of residence is also likely to have a significant impact on cost as those in remote areas are less likely to have access to the same types of services women in less remote areas have. Finally, socioeconomic status may also be an indicator of both affordability and general health, which will impact on the types of services used and therefore the costs incurred.

Reproductive history: IVF and mode of delivery are the most notable factors in this category and their impact on cost is predictable given they are such costly procedures (Independent Hospital Pricing Authority, 2015; Medicare Australia, 2015). Women who have IVF are also more likely to be monitored carefully during their pregnancies and possibly even postnatally. Their reproductive history is likely to be complicated given their use of IVF and may be an indicator of a need for more complex services during the perinatal period. Caesarean delivery is a much higher cost procedure than vaginal delivery so this is highly likely to have an impact on cost, particularly for hospital costs. It may also impact on out-of-hospital costs if the recovery periods from a particular type of delivery is protracted and/or complicated. Finally, the existence of previous adverse births and a problematic reproductive history may also be associated with an elevated cost as these women are likely to be monitored closely even during successful pregnancies and, indeed, may also be classed as “high risk” and receive specialist care (even if they are public patients).

Health behaviours: It is likely that all of the health behaviours discussed above (smoking, alcohol use, low levels of physical activity, high and low body mass index, obesity, poor pre-pregnancy and pregnancy diet and medication use) will have

an impact on maternal health system costs as they are specifically related to the poor health of the woman, and therefore it is foreseeable that they are likely to increase the woman's health service use and possibly even require more expensive services (such as specialist services). Even if this facet manifests simply through increased GP visits, this will have a cost implication (through out-of-hospital costs).

Psychological and physical wellbeing: Psychological health services are costly as they are often provided through specialist service providers. Treatment for anxiety or postnatal depression will often require GP's to refer the woman to counsellors or psychiatrists. This comes at a significant cost not only because of the increased service use, but also because psychiatric services attract higher costs and higher rebates (note that there are few psychiatric services covered under the MBS). Additionally, monitoring of conditions such as diabetes, hypertension and asthma during pregnancy is costly as they usually require more frequent visits to obstetricians (attracting specialist fees) or GPs. These women are also likely to be classed as "high risk" and receive specialist care (even if they are public patients). There is also evidence to show that intervention programs for diabetes and pregnancy can produce cost savings (Scheffler et al., 1992).

It is clear from these insights that many of the risk factors for adverse birth outcomes are likely candidates for cost risk factors too. The focus of this thesis is to understand these links further by modelling the cost with numerous risk factors including those described above. This approach will provide more statistical evidence for some of the theories discussed above and paint a more complete picture of how these risk factors impact specifically on cost.

2.4 Conclusion

There was limited research in the area of maternal health system costs associated with adverse births and, in particular, with regard to understanding the risk factors that drive the costs. However, there were some consistent themes from the research – namely, there was a paucity of research in the area but there were possibilities for health policy benefits in understanding these cost differentials because they were substantial in cases for which they were quantified (Chollet et al., 1996; Gilbert et al., 2003; Gold et al., 2013; Luke et al., 1996; Mistry et al., 2013; Petrou & Khan, 2012; Ringborg et al., 2006). Consequently these issues require more in-depth research. This thesis draws upon these themes and substantially broadens the scope previously considered by tackling a number of aspects of maternal health system costs.

Firstly, the statistical methodology employed in this thesis ensures that maternal health system costs of adverse birth outcomes can be analysed by using a number of both demographic and non-demographic covariates available in an extensive dataset including numerous linked administrative datasets. This dataset and methodology provide insights into both cost differentials and the cost risk factors that was important information to shed light on factors which were driving these costs. Previous research showed the critical impact certain demographic factors, reproductive history, health behaviours, and psychological and physical wellbeing had on adverse birth outcomes. However, the impact these risk factors have on cost is largely unknown, and this topic is the focus of this thesis. The availability of an extensive dataset that contains information on these key risk factors will enable this analysis to consider the relationship between these factors and costs.

Secondly, the scope of the papers reviewed was generally restricted to hospital (or admitted patient costs) only (with the exception of Mistry et al. 2013 and Chollet et al. 1996). The scope for this thesis includes both hospital and out-of-hospital costs. Further, few papers consider the complete perinatal period – that is, antenatal, delivery and postnatal time periods which will all be covered in this thesis. Also, in terms of the definition of adverse births, the scope of the reviewed papers was generally restricted to stillbirths, premature and low birthweight adverse births only. This thesis will expand the definition of adverse births to include congenital conditions and neonatal deaths where relevant data are available. Finally but importantly, this will be the first such study using Australian data.

These analysis will ensure that a much more comprehensive and analytical view of maternal health system costs of adverse birth outcomes is achieved than has been attempted before and it will also give new information on the maternal costs of adverse births in Australia.

3 Methods

It was evident from the preceding literature review that there was little relevant research in the area of maternal health system costs in relation to adverse birth outcomes, particularly research that considers in-depth statistical analysis. However, the findings from the previous research also showed that there were substantial benefits from understanding these cost differentials and that they were significant when quantified. This chapter describes the data and methods used in this thesis to quantify these cost differentials and cost risk factors, with particular focus on the statistical and actuarial techniques employed. Sophisticated techniques such as those used in this thesis have not been applied in previous research in this area, and these techniques contribute to this area by providing a more comprehensive understanding of the underlying drivers of maternal health system costs with particular focus on the significance of adverse births on these costs. In particular, by including a large number of covariates within a multivariate statistical analysis of maternal health system cost, each cost risk factor was considered in the presence of numerous other factors (including adverse births) in order to identify which cost risk factors were the most significant *given the impacts of all other factors*. This feature, in turn, will identify the most important areas on which to focus policy recommendations to improve the outcomes for these women in a cost-effective manner.

Given the aims of this thesis, the analysis was split into two separate but related costing studies (hospital and out-of-hospital costing). The data used for both of these studies were drawn from the Australian Longitudinal Study on Women's Health (ALSWH) and administrative data that have been linked with the survey data. This chapter will describe the ALSWH and administrative data in more detail, including

the data linkages undertaken. In addition, the statistical methods used in both costing studies were similar and will also be described here.

It is also important to note that all the data used in the analysis was obtained on a de-identified basis and all ethical clearances were obtained from the appropriate Human Research Ethics Committees in order to conduct this study (including the Australian National University, University of Newcastle and NSW Population and Health).

3.1 Australian Longitudinal Study on Women's Health

The ALSWH is a national longitudinal survey of over 40,000 women in three age cohorts (born 1973-78, 1946-51 and 1921-26). The postal surveys have been running for twenty years and women were randomly recruited to the survey through the Medicare database and are generally surveyed every three to four years. ALSWH provides a richness of information in women's physical and mental health; psychosocial aspects of health (socio-demographic and lifestyle factors); and use of health services.

The factors available from the survey will play an important role in the covariates of statistical cost models. Further information is available on the ALSWH website at www.alswh.org.au, and details of the schedule of surveys can be found in Table 3.1 below (all surveys used in the 1973-78 cohort were used in this thesis). One of the major benefits of using this survey was its longitudinal design, that is, each participant was repeatedly measured over time. Over 40,000 women consented to participate in the survey in 1996 – 14,247 in the 1973-78 cohort, 13,715 in the 1946-51 cohort and 12,432 in the 1921-26 cohort. All participants completed the initial mailed survey in 1996, and from 1998 onwards each cohort has completed follow-up

surveys on a three- yearly basis. Table 3.1 shows which year each survey was completed for each cohort.

Table 3.1: Schedule of ALSWH surveys 1996-2012

	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
1973-78	S1				S2			S3			S4			S5			S6
1946-51	S1		S2			S3			S4			S5			S6		
1921-26	S1			S2			S3			S4			S5			S6	

ALSWH data may also be linked with various external administrative datasets. There is routine linkage with the national death index to trace any participants that have passed away during survey periods. There is also the ability to link ALSWH data with state-based Cancer Registry, Perinatal and Admitted Patients datasets for most Australian states and territories and national Medicare, Pharmaceutical and Aged Care datasets. The linkage of ALSWH data to Medicare and Admitted Patients data is of particular importance for this thesis as the maternal health system cost data that is used for the analysis is obtained from these administrative datasets for the costing studies. The administrative datasets used in this thesis and the linkages undertaken are described in more detail in Section 3.3 and Section 3.4 for the hospital and out-of-hospital costing study respectively.

3.1.1 The ALSWH 1973-78 cohort

This thesis used all six surveys available for the 1973-78 cohort in both costing studies. These participants have now completed six surveys and answered questions relating to physical and mental health, demographics, health service use, health behaviours and – of particular relevance to this thesis – questions relating to childbirth and motherhood.

As described above, the participants were randomly selected from the Medicare database, with 36,000 women originally invited to join the longitudinal study. As reported by Brown, Dobson et al. (1999) the response rate was estimated to be 41-42% but cannot be precisely calculated due to inaccuracies in the Medicare database. Also, no follow up could be conducted with non-responders as no personal details were known. Brown, Dobson et al. (1999) also compared the demographic profile of the sample of 14,247 that completed Survey 1 to 1996 Census data and the sample was determined to be an adequate representation of that age group; although, there was some over-representation of tertiary-educated women and an under-representation of women from culturally and linguistically diverse (CALD) backgrounds. The following table articulates the retention rates for each survey, showing a retention rate of over 60% for each subsequent survey (Australian Longitudinal Survey for Women's Health, 2014).

Table 3.2: ALSWH retention and attrition for 1973-78 cohort

Year	Survey 2 2000	Survey 3 2003	Survey 4 2006	Survey 5 2009	Survey 6 2012
Age (in years)	22-27	25-30	28-33	31-36	34-39
Deceased	22	33	49	57	76
Frailty (e.g. intellectual disability)	3	9	12	15	16
Withdrawn	230	518	800	951	1,157
Total ineligible	255	560	861	1,023	1,249
Contacted but did not return surve	1,332	653	1,371	1,994	3,604
Unable to contact	2,972	3,953	2,870	3,030	1,474
Total non-respondents	4,304	4,606	3,041	5,024	5,078
Respondents completed survey	9,688	9,081	9,145	8,200	8,010
Eligible at current survey	13,992	13,687	13,386	13,224	12,996
Retention rate as % eligible	69.2%	66.3%	68.3%	62.0%	61.6%

The major reason for non-response among this cohort was the inability to re-contact the participants. This is most likely due to women in this age group having high levels of mobility, changing of surnames on marriage, often not having telephone listings, not being registered to vote, and making extended trips outside Australia for work, education, or recreation (Australian Longitudinal Survey for Women's Health, 2014). Despite these losses, modelling has indicated there is no serious bias in estimates of associations between risk factors and health outcomes in longitudinal models (J Powers & Loxton, 2010).

It is also worth noting here that numerous patterns to survey completion are possible, with for example, a number of participants only completing Survey 1 in 1996 and then Survey 5 in 2009. This is due to the numerous tracing strategies that are employed to retain participants (Adamson & Chojenta, 2007) including mailing an annual newsletter and following up on participants whose mail is returned to sender. These strategies were employed to give participants an opportunity to re-connect with the survey whenever possible. However, many participants were not contactable or were unable to complete a survey at any given follow-up, as seen in Table 3.2.

There are a number of strengths of using ALSWH data for this analysis. Firstly, the longitudinal nature of these data is essential to quantify the ongoing health system cost of women who have experienced adverse birth outcomes, as these data contain information on ongoing health events and outcomes following these births. It also allows the linkage of women to subsequent births so that ongoing costs can be assessed. So, for example, with longitudinal data, the likelihood of whether women experience repeated adverse birth outcomes and similar health issues resulting in higher costs to the health system may be assessed. Secondly, the span of the

participant ages covers key childbearing years, including data from women aged 18-36 years. These data also provide excellent coverage of the perinatal period – commencing from the antenatal period, moving into the delivery period and concluding with the postnatal period. Finally but importantly, the breadth and depth of factors covered in the survey, with over 100 factors requested for this project give important insights into the woman's life. In addition to this, the availability of more detailed information on each of the births, including whether the births were adverse or not are central to the out-of-hospital costing study.

3.2 Summary of datasets for modelling

Both costing studies employ the use of the ALSWH data linked with other datasets for modelling purposes. The following table reports on the final numbers of women and babies used for modelling and the datasets that were used in each study.

Table 3.3: Summary of ALSWH data for modelling

	Out of hospital	**Hospital**
Number of women Number of babies	2520 4546	1875 3400
Datasets used for linkage	ALSWH Medicare Benefits Schedule	ALSWH Perinatal Data Collection Admitted Patients Data Collection Congenital Conditions Registry Perinatal Death Review Australian Bureau of Statistics (ABS) Register of Births, Deaths and Marriages ABS Mortality Data (Deaths only)
Dataset used to define births Dataset used to define cost	ALSWH Medicare Benefits Schedule	Perinatal Data Collection Admitted Patients Data Collection

The final numbers of women and babies used in each study were lower than the total number of ALSWH participants largely because this thesis only considers women who have had babies and not all ALSWH participants have had babies. Further, the linkages required for the hospital costing study were undertaken by the Centre for Health Record Linkage (CheReL) based on a probabilistic linkage of ALSWH women to the administrative datasets and linkages were possible for 5670 babies (from 2688 women). For the out-of-hospital study, the linkage was also restricted by the availability of data for adverse birth outcome status which was most comprehensively covered in Survey 6 through questions relating to each child the woman has had (herein referred to as "ALSWH child/mother" data). Therefore, the 12,692 babies (from 5836 women) available from Survey 6 ALSWH child/mother

data were considered for the analysis. The key reason why babies (and possibly women if they didn't have other babies in the dataset) were dropped from these starting points was due to issues with linkages between birth data and cost data (from administrative datasets). This issue and others which impacted on the data linkage are described more fully in Section 3.3.2 and Section 3.4.2 for hospital and out-of-hospital data respectively. Data reconciliations from this starting point to the final figures show in the table above are also contained in these sections.

The key datasets for modelling were those that were used to define the births and costs (as the modelling was considered on a per-baby unit basis and the response variable was cost, which is discussed further in Section 3.3.2). The other datasets were used largely to provide information on whether an adverse birth occurred (particularly in the case of hospital costing) and also to provide additional covariates for use in modelling. Further additional covariates were created to better address the aims of this thesis (such as an indicator for adverse births), and all variables used in the studies (including their data source) are shown in Appendix A. The formats applied to these variables are also shown in this appendix for ALSWH variables (which were the main variables used as covariates in the models) however for the administrative datasets these formats have been provided in the CD due to the size. The datasets noted above within each costing study are discussed in more detail in the next two sections.

3.3 Hospital costing data

3.3.1 Data sources

The Centre for Health Record Linkage (CheReL) linked ALSWH data with the following New South Wales administrative datasets:

- Perinatal Data Collection;
- Admitted Patient Data Collection;
- Register of Congenital Conditions;
- ABS Mortality Data (ABS Death);
- Perinatal Death Review; and
- Register of Births, Deaths and Marriages (Deaths only).

CheReL used personal information and probabilistic data linkage methods to perform record linkage between all of these datasets and provide the data custodians a Project Person Number (PPN) and the Record ID from the source database. The data custodians then forwarded the PPNs and de-identified datasets (that is, with personal identifiers such as name, date of birth and address removed) to the study investigators to link together as required for the study. Further details of the linkage for the purpose of this thesis are in Section 3.3.2. Note that only NSW data was approved for this linkage. A summary of the key characteristics of each dataset as provided by CheReL is given below.

3.3.1.1 Perinatal Data Collection

The NSW Perinatal Data Collection (PDC) is a population-based surveillance system covering all births in NSW public and private hospitals, as well as homebirths (Centre for Health Record Linkage). Reporting of all births in NSW to the PDC is a

statutory requirement under the NSW Public Health Act, 1991. Data are collected by the attending midwife or medical practitioner and provide a wealth of information on all live births, and stillbirths of at least 20 weeks gestation or at least 400 grams birthweight, as follows:

- demographic information on the mother (for example, date of birth and marital status);
- medical and obstetric information on the mother;
- information relating to the labour and delivery;
- condition of the infant at birth (for example, gestational age and birthweight);
- maternity care (including model of care and place of birth);
- postnatal care of mother and baby; and
- discharge status of mother and baby.

This dataset provided the cohort of babies that will be used in the analysis and a number of variables that were used to identify adverse birth outcomes status.

3.3.1.2 Admitted Patient Data Collection

The NSW Admitted Patient Data Collection (APDC) is administered by the NSW Ministry of Health. The data contain records of all inpatient separations (discharges, transfers and deaths) from all public, private, psychiatric and repatriation hospitals in NSW, as well as public multi-purpose services, private day-procedure centres and public nursing homes (Centre for Health Record Linkage). Patient separations from developmental disability institutions and private nursing homes are not included. While the APDC includes data relating to NSW residents hospitalised interstate, names and addresses are not included on these records and therefore cannot contribute to record linkage studies. Reporting to this data collection is a requirement

under the Health Service Act 1997 for public hospitals, and the Private Health Facilities Act 2007 and Health Insurance Act 1973 for private hospitals.

Public hospital APDC records relate to an episode of care (EOC). An EOC refers to a period of stay in hospital, starting with the admission of the patient and ending with the discharge, transfer or death of the patient. An EOC can also end if the patient is classified as a different "type" of patient within the same period of stay. The different types of patients include (but are not limited to) acute care, rehabilitation care, palliative care, maintenance care and newborn care. For private hospitals, each APDC record represents a completed hospital stay which may be composed of one or more EOC, each of which is defined by a single care type (for example acute care, palliative care or rehabilitation care) and the records are counted based on the separation from hospital.

The APDC provides comprehensive information relating to:

- Australian Refined Diagnosis-related group (AR-DRG) code for each separation;
- ICD codes for each episode of care;
- Duration of stay, and dates of admission and discharge;
- Some demographic information (for example, marital status); and
- Transfers.

3.3.1.3 Register of Congenital Conditions

The NSW Register of Congenital Conditions (RCC) is a population-based surveillance system established to monitor congenital anomalies detected during

pregnancy or at birth, or diagnosed in infants up to one year of age (NSW Ministry of Health, 2012). Scheduled congenital conditions include:

1. All structural malformations. Examples include: spina bifida; microcephaly; transposition of the great vessels; ventricular septal defects; pulmonary agenesis; polycystic lungs; duodenal atresia; exomphalos; hypospadias; cleft lip/palate; microphthalmia; limb reductions; polydactyly; birthmarks greater than 4 cm diameter; cystic hygroma; and multisystem syndromes including at least one structural malformation.
2. Chromosomal abnormalities. Examples include Down syndrome and unbalanced translocations.
3. Four other medical conditions: Cystic fibrosis; phenylketonuria; congenital hypothyroidism; and thalassaemia major.

As a condition of human research ethics approval, only records from this dataset that were identified within the first 28 days after a birth are available.

3.3.1.4 Perinatal Death Review

The Perinatal Death Review Database (PDRD) includes information on perinatal deaths in NSW. Perinatal deaths are currently defined as all deaths of liveborn babies within 28 days of birth, regardless of gestational age at birth ("neonatal deaths"), and stillbirths of at least 20 weeks gestation or 400 grams birthweight (Centre for Health Record Linkage). However, the requirements for babies to be included in the PDRD have changed over time as follows:

1. From 2000 to 2005: all perinatal deaths (stillbirths and neonatal deaths) in NSW of at least 500 grams birthweight or 22 weeks gestation; and

2. For 2006 and subsequent years: stillbirths of at least 400 grams birthweight or 20 weeks gestation, and all neonatal deaths.

The information included is obtained from confidential reviews carried out by the NSW Maternal and Perinatal Committee, which is a quality assurance committee appointed by the Minister for Health to review perinatal morbidity and mortality in NSW. Deaths are classified according to the Perinatal Mortality Classifications of the Perinatal Society of Australia and New Zealand.

3.3.1.5 Register of Births Deaths and Marriages

Perinatal deaths are registered by the Registry of Births, Deaths and Marriages (RBDM) in each State and Territory (Centre for Health Record Linkage). The register of births, deaths and marriages also includes perinatal deaths, comprising stillbirths ("fetal deaths") and deaths of infants within the first 28 days of life ("neonatal deaths"). Fetal deaths are registered only as a birth, while neonatal deaths are registered first as a birth and then a death. This dataset was used to identify deaths that would have been in the PDRD.

3.3.2 Data linkage

As described in section 3.3.1, CheReL was tasked with record linkage between these datasets and the linked data were then provided to ALSWH on a de-identified basis. For the purpose of this study, another extensive data cleaning and linkage process was required to ensure the data were fit for the purpose of modelling. In order to specify the data requirements for the final dataset, there were a number of important considerations and they are discussed below.

Firstly, it was important to consider an appropriate "exposure" measure as this provides key insight into possible response variables. Actuaries refer to the term "exposure" to represent a measure of an underlying risk feature of a cost, particularly in relation to insurance costs (Hart, Buchanan, & Howe, 2007). The measure of exposure should be proportional to the costs incurred, and in this case a logical choice for exposure was a baby, as aggregation at baby level provides a good representation of the risks underlying the cost and is also proportional to the cost. Therefore, the response variable of interest was the "maternal cost per baby" and the dataset needs to be aggregated to one record per baby in order to capture and subsequently model the response variable in this way. Note that for women who have had many babies over the study period, their attributes were considered as covariates in the models for each of their babies and this is exactly what is required to understand statistically whether these attributes were significant in explaining costs.

Consequently, the potential cost risk factors associated with the mother needed to be attributed to each baby so they may be used as covariates in the models. As the cost risk factors need to be considered at the time the baby was born (to represent the mother's cost risk factors at time of birth), these data were assigned using dates of birth and other relevant dates (depending on the data being assigned).

Finally, maternal cost data were sourced from the APDC using the AR-DRG codes and these costs were also separated into antenatal, delivery and postnatal periods for each baby. More details on this costing approach are explained in Chapter 3. The definitions for antenatal, delivery and postnatal periods were as follows:

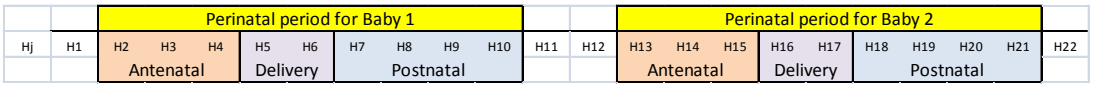
Antenatal period: This period was used to reflect the pregnancy period and capture specific costs associated with antenatal care. This period commenced at the start of the pregnancy, and this was estimated using the variables *gestage* and *bdob* (from the APDC), which refer to the gestational age of the baby at birth (in completed weeks) and the baby's date of birth, respectively. Therefore, the antenatal period starts at *bdob-gestage*7.* The period ended eleven days prior to the baby's date of birth as this time was when the delivery period started.

Delivery period: This period was used to reflect the days leading up to labour and the delivery event itself, and captures specific costs associated with labour and delivery procedures. This period commenced ten days prior to the baby's date of birth and ended on the baby's date of birth. The period of ten days leading up to the delivery date was selected to yield an approximation of possible costs that may be incurred as the woman gets closer to going into labour and subsequently giving birth.

Postnatal period: This period was used to reflect the time after the woman has given birth and the cost associated with that care. This period starts on the day after the baby's date of birth and ends 365 days following the baby's date of birth.

These time frames are illustrated in the following exemplar timeline where a woman has had two babies.

Figure 3.1: Timeline for hospital record data linkage



Hj refers to the j^{th} hospital separation for the mother (based on admission date) for the time period analysed. H1, H11, H12 and H22 are omitted from the analysis as

they fall outside the antenatal, delivery and postnatal periods. H2-H4 are assigned to the antenatal period for Baby 1, H5 and H6 to the delivery period for Baby 1 and H7-H10 to the postnatal period for Baby 1. Note, there is the potential for the postnatal period to overlap with the antenatal period of a subsequent baby and, if this occurred, the hospital records were assigned to the antenatal period of the second baby.

Table 3.4 shows how each of the datasets used in this study were assigned to either cost related data, birth related data or risk factors (some datasets such as the APDC were assigned to more than one of these types of data). Each of these types of data were linked together to create one dataset that was fit for the purpose of modelling.

Table 3.4: Data types for linkage

ALSWH	APDC	PDC	CCR	ABS	PDR
Risk factors	Cost data Risk factors	Birth data Risk factors	Birth data	Birth data	Birth data

The steps required to create the final linked dataset were as follows (linkage keys are in italics with the following definitions: *PPN_Baby* refers to the baby's PPN; *PPN_Mum* refers to the mother's PPN,; *gestage* refers to the gestational age of the baby at birth (in weeks); *bdob* refers to the baby's date of birth; and *adm_date* refers to the admission date of the EOC from the APDC:

1. Using the cohort of babies from the PDC, attach every record from each of the PDRD, ROCC and RBDM by *PPN_Baby*. These datasets were used to describe whether there was an adverse birth outcome or not.
2. Attach the APDC to the PDC by *PPN_Mum* (necessary because the APDC only contains records for the mother) and using the following date restriction:

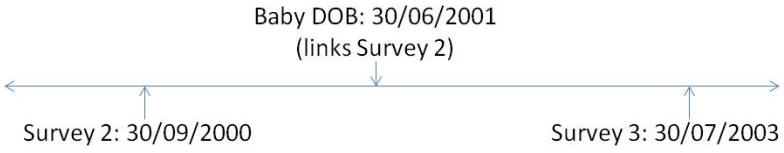
*bdob-gestage*7 > adm_date > bdob+365.* If *adm_date* falls outside of this date restriction, the APDC record is dropped from the linked data as it does not fall in the antenatal, delivery or postnatal period. Note that it is possible to have many APDC records attach to one PDC record as it was relatively common for there to have been multiple hospital separations during each of the periods of analysis.

3. Babies with "incomplete" antenatal and delivery periods were excluded from the data as they have the potential to understate the costs. A period was deemed incomplete if it did not cover the entire period defined earlier. This should not occur for postnatal periods as the APDC end date was more than one year after the end date of the PDC.
4. Removed multiple births and two clearly erroneous data values (*PPN_Baby* for these entries are '00000009008914' and '00000009008870') due to duplicates in the probabilistic linkages undertaken by CheReL. Multiple births tend to have very different characteristics compared to single births, particularly when considering adverse birth outcomes, and could therefore distort the analysis. Multiple births also tend to have a higher chance of experiencing an adverse birth outcome and the modelling techniques will need to be different in any case, as two babies correspond to a single birth event. There were no multiples greater than two in the data.
5. The next step in the data linkage process was to attach the ALSWH data to the linked APDC/PDC dataset. As the ALSWH surveys were conducted every 3 to 4 years, there was a very strong likelihood of a mismatch between survey dates and the babies' dates of birth. In an ideal situation, the survey responses would be as at the baby's date of birth, so that the potential cost

risk factors would faithfully represent the information of the woman at the exact time of birth. Given this was not possible with the data available, the ALSWH survey data were linked to the APDC/PDC dataset using *PPN_Mum* and the closest match of baby's date of birth (from the PDC) to the "date survey returned" (from the ALSWH) as the aim was to link the ALSWH survey to the baby's date of birth that was most relevant by date. Finally, the record was omitted from the data if the ALSWH survey date was more than 4 years from the baby's date of birth, because the survey information would be less representative of the actual characteristics of the woman at the time of birth the further the survey was from the date of birth. As a consequence, the associated covariates in such cases were likely to be unreasonably inaccurate, and may cause substantial bias in modelling. The cut-off of 4 years was selected as it represents a maximal survey cycle.

Figure 3.2 illustrates how this linkage would be undertaken for a baby born on 30/06/2001. Survey 2 data would be linked to this baby as the baby was born closest in date to when that survey was returned compared to Survey 3; hence the responses from Survey 2 would be a more appropriate indication of maternal cost risk factors when that baby was born.

Figure 3.2: Timeline of survey record data linkage



6. The final step was to allocate the hospital records into antenatal, delivery and postnatal periods based on *adm_date* and summarise the data to a maternal cost per baby (by aggregating costs by baby).

3.3.2.1 Data issues and reconciliations

There were a number of data anomalies that were discovered during the data cleaning process and are described below:

- Two error babies as notified by ALSWH (*PPN_Baby* is '00000009008914' and '00000009008870') due to duplicates in the probabilistic linkages undertaken by CheReL.
- Missing records for survey data.
- Missing AR-DRG codes. This represented less than 1% of the APDC hospital records and as a result 0.1% of the babies are omitted.
- Some women in the PDC are not in the APDC. As most of these babies have hospital-related information on them in the PDC for the delivery (and consequently are not homebirths) it is assumed that this discrepancy relates to missing records in the APDC. Therefore, the corresponding babies are also omitted from the data as they will not have a cost assigned to them. This represents less than 0.5% of the babies so it is not a material issue.

In summary, the babies omitted from the data included:

- Babies born prior to July 2000 (as the APDC data are only available from July 2000, babies born prior to this date were omitted as a cost could not be assigned to them);
- Multiple births;

- Two clear errors;
- Babies with no hospital records;
- Babies with incomplete cost periods;
- Babies with survey responses more than 4 years from date of birth; and
- Babies with missing AR-DRG codes.

Table 3.5 describes how many records were retained as well as omitted (and thus lost to analysis) during the data linkage process for the reasons articulated above:

Table 3.5: Hospital data reconciliation

Reconciliation of omitted babies	Number of babies	% of babies omitted
Babies at start (PDC)	5,670	
Multiple births	136	2%
Babies born prior to APDC start date (01Jul2000)	970	17%
Error babies	2	0%
No hospital record for mother	19	0%
Incomplete antenatal or postnatal periods	219	4%
Cost is missing	3	0%
Babies dropped for falling outside 4 yr ALSWH link limit	921	16%
Total dropped babies	2,270	40%
Total babies	3,400	

3.3.3 Hospital costing factors

There were over two hundred factors available to be included as covariates in the multivariate cost models after the data linkage of all the administrative datasets with ALSWH. A complete list of these factors is contained in Appendix A with further details in the accompanying CD, noting that only data from the data sources described in Section 3.3.1 apply to hospital costing models. In this section these factors are discussed within a number of broad categories to explain the types of

factors that were included in the models. Note that while all of the factors relating to hospital data were included in the exploratory analysis, only a subset of the factors were taken forward into the formal parametric modelling following the results of the exploratory analysis. Further details of this modelling process are in Section 3.6.3.

Health service use: These factors were available from the ALSWH surveys and give information on the types of services that were used. The APDC also gives information on each hospital visit that occurred during the time frame studied. Key health service use factors were frequency of GP consultations, specialist use and whether the woman had private health insurance or was a private or public patient.

Obstetric factors: These factors were available from the PDC and ALSWH surveys and related to items regarding the specific details of the labour and delivery period and the health of the baby at birth. The key factors were items such as mode of delivery, pain relief and labour onset. Factors relating to the health of the baby were available from the PDC and included items such as gestational age and whether the baby was resuscitated or required neonatal intensive care.

Reproductive factors: These factors were available from the PDC and ALSWH surveys and give information on the reproductive history of the woman. The key factors in this category were adverse birth, previous adverse birth, infertility and IVF.

Demographic factors: Numerous demographic factors were available from the PDC, APDC and ALSWH. Many were related to the area of residence or area of hospital, and ALSWH also contained key factors such as socio-economic indices (SEIFA indices), education, income, occupation and marital status.

Health behaviours: These factors were available from the ALSWH surveys and key factors were smoking status, alcohol use, drug use, body mass index and exercise indices.

Psychological and physical health factors: Psychological factors were available from ALSWH surveys and key factors were stress about own health, anxiety, postnatal depression and intense anxiety. For physical health factors, both the PDC and ALSWH contained information on various important physical health factors such as diabetes, asthma and hypertension.

3.4 Out-of-hospital costing data

3.4.1 Data sources

The Medicare Benefits Schedule (MBS) data contained the cost data required for this analysis. Note this dataset cannot be linked with the data used for hospital costing due to the prior de-identification of individuals in both datasets.

3.4.1.1 Medicare Benefits Schedule

Medicare is a Commonwealth Government funded scheme for health care services in Australia. Medicare provides access to medical and hospital services for all Australian residents and certain categories of visitors to Australia (Medicare Australia, 2015).

Medicare covers a wide range of services, detailed in the Medicare Benefits Schedule Book (Medicare Australia, 2015). Each service is assigned an item number by the government, and the current Schedule contains over 5700 items. Services are usually provided privately and providers are paid by patients on a fee-for-service basis after which patients are partially (up to 85% of a scheduled fee) reimbursed by

the government. Alternatively, patients may be "bulk-billed", so that they do not pay any fee-for-service and the provider claims 85% of the scheduled fee directly from the government. Importantly, public inpatients are not captured in the MBS data (rather they are captured in the APDC). The impact this has on the data for this analysis is that public inpatients (and possibly even outpatients if they are not billed through Medicare) will not be captured within these data. However, this issue is not material because the data are complete for all Medicare funded services, which is precisely the cost that is being assessed. If a patient is not seen through services covered under the MBS, those services will be funded from elsewhere. The purpose of this analysis is to look at Medicare funding, and the data available are sufficient for that purpose.

MBS data were received for the years 1997-2010. The data were unique by date of service, item number, provider number, bill type, provider charge and benefit amount for each individual for each year. The benefit was the amount that was paid by the government for the service (or "rebate") and is discussed in more detail in Section 5.2.2. There was also a provider charge variable available in the dataset which refers to the amount charged by the provider for the service provided. The information from this dataset that was of critical importance was the rebate along with the dates of service (used to link MBS records to a particular baby). Appendix A contains a complete list of the accessed variables from this dataset.

3.4.2 Data linkage

3.4.2.1 ALSWH-MBS Data linkage

ALSWH survey participants were linked with MBS data using a unique identifier. Initially consent for this linkage was based on an "opt in" basis; however, in 2014

ALSWH was allowed to undertake this linkage on an "opt out" basis. This meant the linkage was performed for all survey participants except those that explicitly refused consent (Australian Longitudinal Survey for Women's Health, 2014). Table 3.6 shows the number of women for which this linkage was undertaken in the dataset used for this analysis:

Table 3.6: ALSWH-MBS data linkage

Survey	Number of women in MBS	Number of ALSWH participants	Linkage rate
1	7327	14247	51%
2	6250	9688	65%
3	5953	9081	66%
4	5913	9145	65%
5	5401	8200	66%
6	5366	8009	67%

Given the linkage rates seen above, further analysis was conducted on Survey 1 (where the linkage rate was the lowest) to assess whether there was any bias in the data from women who were consenters to the linkage. A similar analysis was conducted to previous ALSWH studies which consider linkage biases (Byles et al., 2008) across a number of key demographic characteristics. All the results are shown in Table 3.7 and the significant factors are shown in more detail in Table 3.8 below. The findings were the same in terms of many characteristics of consenters - they were significantly more likely to be better educated, manage on their available income and in better general health but there was no significant difference by BMI, diabetes status and GP consultations undertaken. A number of other demographic factors were also considered here due to the nature of this study, and it was found that the consenters were less likely to be smokers or drinkers but not significantly

different by own health stress, age, marital status or specialist consultations undertaken. It is worth noting here that there was substantial differences in the linkage rates between Survey 1 and Survey 2 so there is another source of bias in the attrition of women and uptake of other women between these surveys.

Table 3.7: Comparison of consenters and non-consenters – model results

Coefficient	Estimate	Std. Error	z value	Pr(>|z|)
(Intercept)	-1.561	0.520	-3.00	2.70e-03
Age	0.026	0.015	1.80	7.23e-02
Marital	0.021	0.011	1.90	5.74e-02
Alcohol	-0.098	0.021	-4.58	4.56e-06
Diabetes	0.279	0.198	1.41	1.59e-01
Consultgp	0.048	0.018	2.60	9.38e-03
Consultspec	0.033	0.025	1.34	1.81e-01
Education	0.010	0.016	6.17	6.72e-10
generalHealth	-0.093	0.025	-3.75	1.77e-04
manageIncome	0.079	0.020	3.96	7.45e-05
Ownhealthstress	0.066	0.023	2.84	4.56e-03
WHObmigroup	0.055	0.028	1.95	5.16e-02
Smokst	-0.071	0.012	-5.85	4.84e-09

Table 3.8: Comparison of consenters and non-consenters – significant factors

	Demographic factor	Non-consent	Consent	Difference
General health	Excellent or very good	48%	54%	6%
	Good, fair or poor	52%	46%	-6%
	Missing	1%	1%	0%
Manage on Income	Impossible/difficult	54%	49%	-5%
	Not too bad/easy	46%	51%	5%
	Missing	0%	0%	0%
Education	University or higher	8%	14%	6%
	Lower than university	91%	86%	-6%
	Missing	1%	0%	0%
Alcohol	Lower rated	77%	80%	4%
	Higher rated	21%	18%	-3%
	Missing	2%	2%	0%
Smoking status	Non smoker	60%	69%	9%
	Smoker	35%	27%	-8%
	Missing	5%	4%	-1%

3.4.2.2 Data linkage for modelling

The MBS data were linked to both the ALSWH child/mother data and the standard ALSWH survey data in order to analyse the out-of-hospital costs in conjunction with the potential risk factors available from ALSWH.

The ALSWH child/mother data were used as this dataset contains the information regarding the adverse birth outcomes of the baby and the ALSWH survey contains information relating to the mother, both of which will be used as covariates in the cost models. Only Survey 6 was used for the ALSWH child/mother data as it contained the most comprehensive questions on adverse births. The steps required to create the final linked dataset were as follows (linkage keys are in italics with the following definitions: *IDProj* refers to the mother's project ID; *bdob* refers to the

baby's date of birth; *datesurveyreturned* refers to the date the ALSWH survey was returned; and *dos* refers to the date of service of the MBS record):

1. Append all MBS data (years 1997-2010) and remove duplicates (see Section 3.4.2.3 below for details on duplicated records).
2. Using the cohort of babies from the ALSWH child/mother data, the MBS data were linked to each child/mother pair as follows. First, the MBS data were attached to the child/mother pair in the ALSWH data that most closely matched by *dos* (from MBS data) and the *bdob* (from ALWSH child/mother data). In other words, the MBS record was attached to the child/mother pair that matched most closely by date. Secondly, if the MBS record was equidistant between two babies' dates of birth, it was attached to the first baby. This phenomenon did not occur often (less than 0.1% of records were impacted) and the impact on the final results was immaterial. This linked dataset will be referred to as the "Cost data" as it contains one record per child/mother pair with cost information attached to it from the MBS data.
3. Plural births were removed from the ALSWH child/mother data as they were out of scope for this analysis.
4. The next step in the data linkage process was to attach the ALSWH data to the Cost data. As the ALSWH surveys were conducted every 3 to 4 years, there was a very strong likelihood of a mismatch between survey dates and the babies' dates of birth. In an ideal situation, the survey responses would be as at the baby's date of birth, so that the potential cost risk factors would faithfully represent the information of the woman at the exact time of birth. Given this was not possible with the data available, the ALSWH survey data were linked to the Cost data using *IDProj* and the closest match of *bdob*

(from the Cost data) to the *datesurveyreturned* (from the ALSWH), as the aim was to link the ALSWH survey to the baby's date of birth that was the closest by date. If the baby's Cost data record was equidistant between two ALSWH surveys, it was attached to the first survey, as this was more likely to coincide with a pregnancy period. Finally, the record was omitted from the dataset if the ALSWH survey date was more than 4 years from the baby's date of birth, because the survey information becomes less representative of the actual characteristics of the woman at the time of birth the further the survey was from the date of birth. As a consequence, the associated risk factors in such cases were likely to be unreasonably inaccurate, and thus potentially cause substantial bias in modelling. The cut-off of 4 years was selected as it represents one cycle in the survey. Figure 3.2 depicts how this linkage took place for hospital costing, and the same principle was applied here.

5. MBS records were defined as small or large (based on their MBS item numbers) following an extensive investigation into multiple modes of the cost distributions. Details of this investigation are in Section 5.3.1.3. Records were defined as large if they had the following item numbers: 16519, 16590, 16522, 16520, 16500, 20850, 18216, 18226, 13200 & 13201 (see Table 5.6 for more details on these item numbers).
6. MBS records were allocated to antenatal, delivery and postnatal periods (for both small and large) based on *dos* and the data were summarised to a maternal cost per baby (by aggregating costs by baby). Records with incomplete antenatal and postnatal periods were also removed as they would

impact the results by underestimating the costs for those periods. A period was deemed incomplete if it did not cover the entire period defined earlier.

After this process was complete, there were 4546 babies and 2520 women in the final dataset used for the analysis – full details of the reconciliation are in Section 3.4.2.3. There were also over 100 variables from the ALSWH survey used as covariates in the models (see Appendix A).

The considerations discussed in Section 3.3.2 for hospital costing also apply here in terms of choice of exposure measure, aggregation of data at baby level and definitions of delivery and postnatal periods. The definition of the antenatal period varied from hospital costing because there was no gestational age variable available in this dataset, therefore the following definition was used instead and uses an approximation for the gestational age:

Antenatal period: This period commenced 300 days prior to the baby's date of birth and ended eleven days prior to the baby's date of birth.

Finally, the definition of public and private patient was made based on the ALSWH question regarding whether the woman had private health insurance. If the answer to this question was "Yes" the woman (and her babies) were deemed to be "private" otherwise they were "public".

3.4.2.3 Data issues and reconciliations

Data duplication

During the data cleaning, a small number of records were found to be duplicated. The duplication occurred with records where the patient saw the same provider, for the same service on the same day and for the same charge and benefit. On further

investigation, and following communication with the MBS Analytics section, it was found that duplicate claims records may be generated in the system. As this duplication could result in double counting, the duplicated records have been deleted. Nevertheless, this was not a material issue, affecting less than 1% of the total cost.

Null records

MBS data also contains null claims. This occurs where the woman has consented to the MBS linkage but has had no MBS claims. These are genuine zero cases, and thus have been treated as such in the data cleaning and subsequent analysis. In order to preserve the zero cases across the three periods being analysed (antenatal, delivery and postnatal), a separate file had to be created for each period of analysis, as a woman could be a null case for one period but not the others.

Data reconciliation

Table 3.9 shows the data reconciliation in terms of omitted babies from the linking process undertaken above:

Table 3.9: Out-of-hospital data reconciliation

Reconciliation of omitted babies	Number of babies	% of babies omitted
Babies at start (ALSWH child/mother data - Survey 6 only)	12,692	
Multiple births	216	2%
Babies with incomplete antenatal or postnatal periods	3,103	24%
Babies with no MBS records	3,768	30%
Babies with no MBS records in perinatal periods	1,030	8%
Babies dropped for falling outside 4 yr ALSWH link limit	29	0%
Total dropped babies	8,146	64%
Total babies	4,546	

The babies with no MBS records correspond to babies where all MBS records were either allocated to a sibling or the woman did not have any MBS records (maybe because of withdrawal of consent). Babies with no MBS records in the perinatal period refer to child/mother pairs that were in the ALSWH child/mother dataset but all the MBS records associated with the pair were either entirely before or entirely after the perinatal period.

Note that these babies were not genuine zero-cost cases, as the data on genuine zero-cost cases were coded as "null" records in the MBS dataset. This data linkage includes these null records and they do not get allocated to these babies either, so these babies were omitted from the analysis.

3.4.3 Out-of-hospital costing factors

There were over one hundred factors available to be included as covariates in the multivariate cost models after the data linkage of the MBS with ALSWH. A complete list of these factors is contained in Appendix A, noting that only data from the data sources described in Section 3.4.1 apply to out-of-hospital costing models. In this section these factors are discussed within a number of broad categories to explain the types of factors that were included in the models. Note that while all of the factors relating to out-of-hospital data were included in the exploratory analysis, only a subset of the factors were taken forward into the formal parametric modelling following the results of the exploratory analysis. Further details of this modelling process are in Section 3.6.3.

Health service use: These factors were available from the ALSWH surveys and give information on the types of services that were used. The MBS data also give information on out-of-hospital services used that were covered under Medicare

during the time frame studied. Key factors in this category were frequency of GP consultations, specialist use and whether the woman had private health insurance.

Obstetric factors: These factors were available from the ALSWH surveys and related to items regarding the specific details of the labour and delivery period and the health of the baby at birth. The key factors were items such as caesarean delivery (both elective and emergency), epidural use and whether the baby required special care at birth.

Reproductive factors: These factors were available from the ALSWH surveys and provided information on the reproductive history of the woman. The key factors in this category were adverse birth, previous adverse birth, infertility and IVF.

Demographic factors: Numerous demographic factors were available from the ALSWH surveys including socio-economic indices (SEIFA indices), education, income, occupation and marital status.

Health behaviours: These factors were available from the ALSWH surveys and key factors were smoking status, alcohol use, drug use, body mass index and exercise indices.

Psychological and physical health factors: Psychological factors were available from the ALSWH surveys and key factors were stress about own health, anxiety, postnatal depression and intense anxiety. For physical health factors ALSWH also provided information on diabetes, asthma and hypertension.

3.5 Adverse birth definition by costing study

Adverse births were defined based on the available data for each costing study. The datasets used for each type of adverse birth is shown in Table 3.10.

Table 3.10: Data used for adverse births definition

Adverse birth	Hospital costing	Out-of-hospital costing
Premature birth	PDC	ALSWH child / mother data
Stillbirth	PDC	ALSWH child / mother data
Low birthweight	PDC	ALSWH child / mother data
Neonatal death	PDC & ABS	N/A
Congenital conditions	CCR	N/A

As seen above, data for neonatal deaths and congenital conditions were not available for the out-of-hospital costing study. An overall adverse birth indicator was also created for each study based on whether the baby was an adverse birth according to any of the types above, and this indicator was used extensively in the modelling.

3.6 Statistical Methods

3.6.1 Modelling framework

A number of statistical tools were used in both costing studies to best model the data. A multivariate modelling approach was deemed most suitable to identify the primary effects of variables that were most significant in explaining variations in cost. Furthermore, generalised linear models (GLMs) or variations of such were attractive for the modelling exercise because of their flexibility in allowing for non-normal error structure and non-linear relationships through the associated link functions.

The overall modelling framework for both costing studies had two phases, an exploratory phase and a formal, parametric modelling phase:

Phase 1 (Exploratory): Classification and Regression Tree (CART) models were used in order to understand which factors were important in explaining variations in

cost. As over 100 factors were available in the initial stages, this approach was an ideal way of selecting important factors to include in the multivariate modelling as the CART models were able to cope with large volumes of covariates (unlike GLMs, for which model convergence becomes difficult as the number of covariates rise). Note that CART is only used here as an exploratory method to narrow down the number of factors to be used in the GLM. Nevertheless, CART models can reveal interesting structure, particularly in terms of interactions between variables, as CART models allow for the same variable to contribute to *each* level in the fitted tree structure, and so complex, non-linear structure can be well approximated.

Phase 2 (Formal parametric modelling through GLMs): An appropriate cost variable was selected for the response and a broad set of factors selected from CART were used as covariates in the GLM. If the adverse births factor was significant, this was evidence to show that there was a significant cost difference between women who had adverse births and those who did not (taking all other tested factors into account).

More details of the statistical techniques and specific details of the process in this framework are provided in Section 3.6.2 and 3.6.3 respectively.

The key benefits of this two-phase approach are:

- The CART process ensures all available factors are taken into account, which allows a pruning of all available factors into a core set of factors for further exploration through formal modelling. Modelling all covariates within the GLM modelling is infeasible, as model convergence was a problem when too many covariates were included.

- The GLM framework provides a formal modelling setting within which the statistical significance of available covariates can be assessed.
- Using certain factors such as year and age in the GLM framework also ensures any cohort effects are taken into account.

The multivariate approach has been used previously in other health costing analyses (Ellis, Fiebig, Johar, Jones, & Savage, 2013; Johar, Jones, & Savage, 2012) and also in actuarial pricing problems for insurance claims costs (Hart et al., 2007). In fact, there are a number of parallels between insurance claims cost modelling and the health system cost modelling, including:

- The cost distributions tend to be right skewed;
- Inflationary effects in the cost data need to be considered;
- Numerous risk factors are considered within multivariate modelling frameworks to identify the key drivers of the cost and understand the true impact they each have; and
- In insurance settings, frequency of a claim and severity of a claim may have different underlying risk factors and are often modelled separately. For health system costing, a similar principle may apply for the frequency of usage of a service and the average costs of services.

Given the last point above, this thesis will also consider "frequency" or number of services (per baby) and "severity" or average cost of service (per baby) models where data allows and they are relevant. The combination of the frequency and severity models is equivalent to a total cost model, so the results should be consistent between the two approaches. The main benefit of considering frequency and severity separately is to gain a better understanding of the underlying drivers of frequency

and severity of cost. For example, it may be the case that women who have adverse births do not use many services (that is, they are low frequency), but when they use a service it tends to be expensive (that is, they have a high severity). Modelling total cost masks these two results. This methodology is commonly found in actuarial literature when modelling claims for general insurance (Hart et al., 2007) as claims frequencies and severities often have different cost risk drivers.

3.6.2 Statistical techniques

This section describes the two key statistical techniques that are used in this thesis: CART and GLMs.

3.6.2.1 CART

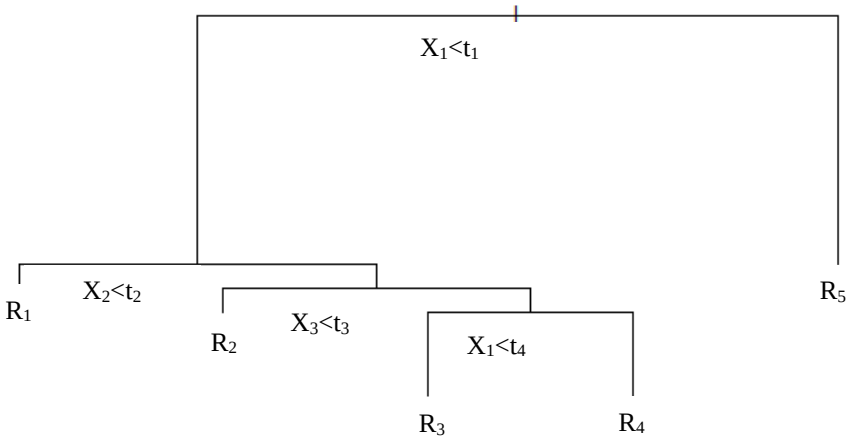
CART is a popular statistical method for "tree-based" regression and classification. The principle behind tree-based methods is to partition (or "split") the sample space into a set of regions and fit simple models for the response variable within each region. The general steps for a CART process follows a "recursive binary partition" and is described as follows (further details are available in Ripley (1996)):

1. Split the space into two regions, and model the response through its mean for each region. The variable selected to perform this split is the one that will give the "best fit" for each region. The criterion for best fit may be based on minimising the sum of squares, which is a commonly used approach for statistical estimation of parameters, although alternative criteria may also be used (for example, in classification problems, one may seek to minimise misclassification rate at each step in the tree algorithm).
2. One or both of the regions are split into two more regions based on the same criteria of best fit for each region.

3. This process is continued on each region until the stopping rule is applied. There is a balance required when determining an appropriate stopping rule as a large tree has a tendency to overfit the data, while a small tree might not capture important features of the data. Therefore, the tree size is a complexity parameter and the optimal tree size balances fit against complexity. The usual method used to prune the trees is called “cost-complexity pruning”, a process in which a large tree is grown, stopping the splitting process only when some minimum node size is reached. This large tree is then pruned such that the subtree (or pruned tree) minimises the cost complexity criterion. This criterion selects the complexity parameter to achieve a trade-off between tree size and goodness of fit to the data. It is possible to show that there is a unique smallest subtree that minimises the cost complexity criterion (Breiman, Friedman, Olshen, & Stone, 1984; Ripley, 1996).

For the purpose of this thesis, this process was followed using R software and the R package “rpart”. There was considerable judgement used in deciding on the stopping rule, because the purpose of the CART process was *not* for model prediction; rather it was used as an exploratory tool to select candidate variables to use in the GLMs. Therefore, where useful cost risk factors were identified in the CART analysis, they were included even if they appeared in parts of the tree beyond the optimal size. This was not a major issue during the modelling process as if the variables selected in CART analysis were considered unimportant in an overfit tree, they would most likely turn out as insignificant in the GLM stage. The benefit of this approach was that it widened the group of potential cost risk factors to be tested in the GLM stage.

Finally, another major benefit of this approach was that the results of the tree model could be represented graphically by a binary tree such as that depicted below:



The tree is interpreted as follows:

- The full dataset sits at the root node of the tree.
- Observations are either assigned to the left or right branch depending on whether they satisfy the condition of the junction. So for example, the first split of this tree splits on the covariate X_1 and observations to the left are those for which X_1 are less than the value t_1 and observations to the right are those for which X_1 are greater than or equal to t_1.
- The terminal nodes (or leaves) of the tree correspond to the regions R_1, ..., R_5.

For the purpose of this thesis, this graphical tree representation enabled useful descriptive explanations of certain groups of women and how their characteristics (such as certain demographics or health behaviours) may impact on cost. These descriptions from the trees allowed more intuitive explanations than similar

interpretations that can be gleaned from traditional parametric modelling frameworks. Tree models have several limitations, however, that limit their use in formal modelling: first, they can exhibit highly variable behaviour (arbitrary splitting), particularly at the extremities of the tree; and second, they do not naturally allow a formal testing framework to assess the significance of variables included in the model. Thus, the final model fitting and selection of significant factors is more readily carried out under a GLM framework, which was the next phase in the modelling framework. Moreover, traditional parametric models are commonly found in the extant literature, and so use of this framework allows this work to be compared to other studies that have similar goals.

3.6.2.2 Generalised linear models (GLMs)

3.6.2.2.1 Traditional GLMs

The idea of a generalised linear model (GLM) was first described by Nelder and Wedderburn (1972). There are three components to a GLM:

1. Response variables Y_1, ...,Y_N which are assumed to share the same distribution from an exponential family.
2. A set of parameters β and covariates.

$$X = \begin{bmatrix} x_1^T \\ \vdots \\ x_N^T \end{bmatrix}$$

3. A monotone link function which defines how the response variable is linked to the explanatory variables.

$$g(\mu_i) = x_i^T \beta \text{ where } \mu_i = E(\mathrm{Y_i})$$

GLMs use the method of maximum likelihood for the estimation of parameters of the model, and these estimates are obtained by an iteratively reweighted least squares procedure. Further details of the theory behind the estimation approach and components of the GLM are covered extensively in various sources (Dobson, 1990; McCullagh & Nelder, 1986). In terms of model adequacy and factor selection, similar methods (such as t-tests and residual analysis) to classical linear modelling are used (McCullagh & Nelder, 1986).

The key advantage of the GLM approach, as opposed to classical linear models is the flexibility in the selection of the error distribution from an exponential family. This is particularly important when modelling costs, as they usually have right-skewed distributions, thus violating the normality assumption required in classical modelling. Therefore, there are applications of GLMs to costing studies in various industries such as insurance (Brockman & Wright, 1992; Hart et al., 2007) and health (Ellis et al., 2013).

3.6.2.2.2 Mixed effects models

An extension to the standard GLM approach above is to consider mixed effects models. These models offer a flexible framework by which to model the sources of variation and correlation that arise from grouped data (which, for example, can arise if data collection is undertaken in a hierarchical manner). Mixed effects models are seen as especially robust in the analysis of unbalanced data when compared to similar analyses done under the GLM framework (Pinheiro & Bates, 2000).

A model with mixed effects contains both fixed and random effects. The covariates that are described in Section 3.6.2.2.1 above are treated as fixed effects, and the model structure assumes the only source of randomness in the models arises from the

cases as independent random samples (Venables & Ripley, 2002). However, some of these covariates themselves may be considered as random effects – that is, these covariates fluctuate randomly over units in the population and so the effect is modelled in terms of the parameters of that distribution rather than estimating a separate coefficient for every level of the covariate factor. Random effects are generally considered most useful where data are grouped in some way. For example, in a study of students if data are collected from different schools, "school" may be a random effect. Students within a school might be modelled in terms of overall "school parameters" (for example, mean and standard deviation) rather than fitting a different effect for each student. In this thesis, hospital (or hospital-related factors) may be considered possible candidates to be modelled as random effects.

3.6.3 Modelling process and model validation

Given the complexities and extent of data available for the modelling phase, it was important to define a modelling process to use across both costing studies. The aim of the process was to ensure the final models were robust and provided the best fit to the data at hand. The following process was used:

1. Exploratory data analysis was conducted to understand the cost distributions and intricacies of the data including any outliers. This step also provided important insight into how the data should be grouped for the purpose of multivariate modelling. This was necessary because the sub-categories provided more homogenous groups that resulted in better fitting models. The sub-categories varied for each costing study and were dependent on the characteristics of the data.

2. Using CART methodology, the most important factors were selected, taking into account the optimal tree size, appropriateness of the selected variables and the number of variables that were likely to be handled by a GLM (without issues with model convergence). As discussed above, this step was undertaken principally as a means of selection of variables to use in the GLMs, as the GLM themselves were unlikely to converge if all variables were used in the model.
3. GLMs were fit for each sub-category for hospital and out-of-hospital costing. Error structures and link functions were selected based on the characteristics of the response variable and other model adequacy tests (see step 4 below). Significant factors were selected from the GLMs using t-tests and using the following process to select variables:
    i) Start with factors from CART for just that sub-category of model (for example, private-antenatal);
    ii) Add factors from other sub-categories of models, starting with private or public then each of the perinatal periods;
    iii) Add other relevant factors that were not selected by CART but that were deemed appropriate to test (for example, diabetes, hypertension, marital status, smoking status, area, adverse births and previous adverse births) because of their potential impact on costs as identified through the literature review in Chapter 2.
    iv) Random effects were considered where relevant.
    v) All two-way interactions were considered, once significant factors were selected from the process above.
4. Two approaches were considered for model adequacy and testing:

i) The robustness of Gamma cost models was tested by also considering the negative binomial distribution family for the underlying error distribution. Similar results in each case suggested that the modelling was robust to the choice of error distribution.

ii) Backward stepwise procedures were used to test the final factors that were selected in the GLMs. These procedures produced very similar results to the standard t-tests.

This process was undertaken for total cost, frequency and severity models. However, frequency and severity models were only considered where data permitted and it was deemed useful.

3.6.4 Conclusion

A two-phase modelling framework will be adopted in each costing study to analyse the maternal health system costs. These two phases relate to exploratory analysis (including CART) and formal parametric modelling (or GLMs). Adverse birth outcomes and other factors from ALSWH data and various other administrative data will be used as potential candidates of cost risk factors (or covariates) in these models. An extensive modelling process is undertaken to ensure that the models will be robust and provide the best fit to the data at hand. Finally, further details of the specifics of the datasets (including the data linkages) and results of the two costing studies are contained in the following two chapters.

4 Results Part 1 – Hospital costing

4.1 Introduction

Hospital costs relate to costs incurred when a patient is admitted to a hospital and represented 92% of expenditure in maternity services in Australia in 2008 (Bryant, 2008). The main procedure that gives rise to the expenditure in this area is the actual delivery of a baby in a hospital. The aim of this chapter is to use statistical and actuarial modelling techniques to identify factors associated with maternal hospital costs, with particular focus on adverse births. The results of the analysis can then be used to develop policy recommendations to ensure cost effectiveness in this area.

4.2 Methods

4.2.1 Summary of data

The datasets used for this study were obtained through the linkage of a number of administrative datasets by CHeReL, in particular, the following administrative datasets were linked with ALSWH data:

- Perinatal Data Collection;
- Admitted Patient Data Collection;
- Register of Congenital Conditions;
- ABS Mortality Data (ABS Death);
- Perinatal Death Review; and
- Register of Births, Deaths and Marriages (Deaths only).

Table 4.1 summarises which years were available for the datasets used in this study. The time frame was constrained by both the APDC and the PDC as both were used

for cost and birth data respectively. There were 1875 women in the final complete dataset used for modelling with 3400 babies (over the years 2000-2012). Section 4.2.2 discusses how the cost variable was calculated using the APDC dataset.

Table 4.1: Hospital datasets

Dataset	**Years**
ALSWH	2000-2012
Perinatal Data Collection	1996-2012
Admitted Patients Data Collection	2000-2013
Congenital Conditions Registry	2000-2009
Perinatal Death Review	2000-2009
ABS Register of Births, Deaths and Marriages	1997-2007
ABS Mortality Data (Deaths only)	1997-2004

Table 4.2 gives summary statistics of some key variables in the final linked dataset.

Table 4.2: Hospital data statistics

Factor	% babies	% cost
IVF		
No	68%	68%
Yes	3%	4%
Missing	29%	27%
Area		
Major cities of Australia	51%	49%
Inner regional Australia	25%	25%
Outer regional Australia	11%	11%
Remote Australia	1%	1%
Very remote Australia	0%	0%
Overseas participants	0%	0%
Missing	12%	14%
Smoking status		
Never smoker	60%	58%
Ex-smoker	27%	28%
Smoker, less than 10 per day	6%	6%
Smoker, 10-19 per day	5%	5%
Smoker, 20 or more per day	2%	2%
Missing	0%	0%
Mode of delivery		
Normal vaginal	59%	48%
Forceps	4%	3%
Vacuum extraction	7%	6%
Vaginal breech	0%	0%
Caesarean section	29%	42%
Not stated	0%	0%
Missing	0%	0%
Patient status		
Mixed	4%	5%
Other	0%	0%
Private	42%	39%
Public	54%	57%
Private health		
No	40%	40%
Yes	60%	60%
Maternal diabetes		
No	99%	99%
Yes	1%	1%
Adverse births		
No	94%	93%
Yes	6%	7%

4.2.2 Cost definition: AR-DRG codes

Every record in the APDC relates to an episode of care which has an Australian-Refined Diagnosis Related Group (AR-DRG) code associated with it. The AR-DRG is a patient classification scheme based on a system of hierarchies of diagnoses and procedures that relates the number and types of patients treated in a hospital to the resources required by the hospital, and hence relates directly to cost. The AR-DRG codes are a well-known classification system for hospital costing purposes (Ellis et al., 2013; Johar et al., 2012; Ringborg et al., 2006). Furthermore, they also have significant uses in health service research, planning and policy development. For the purpose of this study, these codes and corresponding cost information will be used to calculate the hospital costs of the women in the linked data.

The statutory body responsible for developing the AR-DRG classification system has changed in recent years, with current responsibility resting with the Independent Hospital Pricing Authority (IHPA) [10] – formerly resting with the Department of Health and Ageing (DoHA). One of the outputs of the AR-DRG system is cost-weight tables which assign a cost-weight and Australian dollar hospital cost for each AR-DRG code. These cost-weights represent the relative cost of a particular AR-DRG element compared to the average cost of all AR-DRG elements. The system is revised on a regular basis using the most recent data available for both public and private hospitals. The AR-DRG codes recorded in the APDC data for this study use AR-DRG V6.0 for public and private hospitals and AR-DRG V7.0 for some private hospitals and both of these tables are available from the Department of Health.

[10] Details of the AR-DRG classification system are contained here: http://www.ihpa.gov.au/internet/ihpa/publishing.nsf/Content/admitted-acute

As Australian hospitals are managed by the states, there are also state-based cost-weights available. However, the NSW cost-weights do not treat public and private hospitals differently, and as this has a material impact on how maternity services are treated, the National AR-DRG codes and cost-weights were preferred (as they distinguish between public and private hospitals). Furthermore, the NSW cost-weights have not been updated to reflect AR-DRG V6.0 and V7.0, a step required for the dataset in question (NSW Ministry of Health, 2011),

Several adjustments were also applied to ensure greater accuracy with regard to the costs used. The first adjustment relates to a disclaimer provided with the AR-DRG V6.0 table. The disclaimer was as follows[11]:

"DISCLAIMER - These cost weights have been produced from a sub-set of hospitals that provided patient level data for Round 13 (2008-09) of the National Hospital Cost Data Collection. They have been released as interim pending the production of services weights for AR-DRG version 6.0, which will allow a wider sample of hospitals to provide data for production of the cost weights in 2011 (Round 14 - 2009-10). The Department cannot guarantee and assumes no legal liability or responsibility for the accuracy, currency or completeness of the information. Before using the interim cost weights, users should carefully evaluate their relevance to their purpose and should obtain any appropriate professional advice relevant to their particular circumstances."

The more accurate cost-weights referred to within this disclaimer (using a wider sample of hospitals to provide data) have been labelled "AR-DRG V6.x". The key

[11] See the following link: http://www.health.gov.au/internet/main/publishing.nsf/Content/Round_13-cost-reports

changes in the table update from V6.0 to V6.x were as follows (these comments also reference changes made from AR-DRG V6.x to AR-DRG V7.0) (Independent Hospital Pricing Authority, 2012):

- Originally vaginal deliveries (O60) were split into three groups based on complexity. This was aggregated into one group for V6.0 and then disaggregated back to the original three groups in V6.x (and V7.0).
- False labour was originally split into two groups (O64) based on gestation. This was aggregated into one group for V6.0 and then disaggregated back to the original two groups for V6.x. (Note that V7.0 removes these groups completely and incorporates false labour into O66 (antenatal admissions)).
- Antenatal admissions were originally split into two groups based on same day vs overnight admissions and this was aggregated into one group for V6.0. This was then disaggregated back to the original two groups for V6.x (and then further split into three groups for V7.0 which incorporated a complexity grouping as well). Note that care needs to be taken when interpreting codes for antenatal admissions as the same codes have two different meanings between V6.x and V7.0.
- Similar changes occurred in terms of definitions for caesareans (O01) based on complexity when moving from V6.0 to V6.x.

The consistent practice in the changes from V6.0 to V6.x was that V6.0 aggregated many key obstetrics codes into a single code and V6.x then disaggregated them into codes usually differentiated by complexity. The impact of these changes was less accuracy in cost categories for key obstetric items in V6.0 compared to V6.x. Furthermore, as the cost-weights derived in V6.0 tables were not warranted as being

as reliable as for V6.x (as explained in the disclaimer above), it was decided to use V6.x to estimate the costs and make adjustments for grouped codes. The most logical way to adjust for the grouping was to use a weighted average of the ungrouped AR-DRG codes in V6.x to approximate the grouped AR-DRG codes where relevant. The logical weights to be used were proportional to the number of separations (equal to the number of episodes of care). Weighted averages were used for the following codes: J06Z, J07Z, O60Z, O64Z, O66Z, U61Z, U63Z, V60Z, O01A and a brief description of what the codes refer to are shown in Table 4.3 below.

Table 4.3: Descriptions of adjusted AR-DRG codes

J06Z	Major Procedure for Breast Conditions
J07Z	Minor Procedure for Breast Conditions
O60Z	Vaginal Delivery
O64Z	False Labour
O66Z	Antenatal and Other Procedure
U61Z	Schizophrenia Disorders
U63Z	Major Affective Disorders
V60Z	Alcohol Intoxication and Withdrawal
O01A	Caesarean Delivery

All codes, related to the first three digits of the codes above, were used in the weight with the exception of the last one which uses only O01A and O01B from V6.x. Finally, O01B from V6.0 was allocated to O01C in V6.x as both relate to uncomplicated caesareans.

The second adjustment was to inflate all costs to the same time period as each AR-DRG table used data for costs at different instants in time. This was done to ensure that all costs were expressed in consistent money terms when modelling. An

inflation rate of 3% p.a. was used to be consistent with the inflation measure applied by IHPA (Independent Hospital Pricing Authority, 2015) to inflate costs to 2015-16 values. Table 4.4 describes which AR-DRG table was used for each combination and how the inflation adjustment was applied.

Table 4.4: Inflation adjustment applied to average AR-DRG costs

Hospital type	**AR-DRG version**	**% of records**	**As at year**	**Inflation required**
Private	V6.0	22%	2008-09	7 years
Private	V7.0	10%	2012-13	3 years
Public	V6.x*	68%	2011-12	4 years

*with adjustments described earlier

The final adjustment was to use the equivalent public cost if the private AR-DRG code was missing for a record in the data. This adjustment was required for approximately 1% of records.

4.3 Results

The modelling was split into three phases: exploratory analysis, classification and regression trees (CART) and generalised linear models (GLMs) and the results of each are discussed in turn.

4.3.1 Exploratory analysis

The aim of the exploratory analysis was to better understand the data and explore specific areas of the data that will impact on key modelling decisions in more detail. Most of this was conducted on a one-way basis so cannot capture complex

interrelationships amongst multiple variables within the data. The CART and GLM procedures address more complex multivariate structure in the data.

4.3.1.1 Costs of adverse births

The following tables summarise the data by adverse births and related hospital costs.

Table 4.5: Summary of maternal hospital costs by adverse births

Adverse birth	Antenatal	Delivery	Postnatal	Total	No. of babies
No	1,457,283	22,717,456	3,063,969	27,238,709	3,193
Yes	227,803	1,735,961	205,731	2,169,495	207
Total	1,685,087	24,453,417	3,269,700	29,408,203	3,400
% of total	6%	83%	11%	100%	6%

Table 4.6: Summary of average maternal hospital costs by adverse births (Ab)

Adverse birth	Antenatal	Delivery	Postnatal	Total
No	456	7,115	960	8,531
Yes	1,100	8,386	994	10,481
Total	496	7,192	962	8,649
Ab: non-Ab	2.41	1.18	1.04	1.23

Table 4.5 and Table 4.6 showed that overall average maternal hospital costs were 23% higher when there was an adverse birth, compared to when there was no adverse birth. The cost differences were highest in the antenatal and delivery periods, however, relatively low overall costs occurred within the antenatal and postnatal periods as the delivery period represented over 80% of the total maternal hospital cost. Table 4.5 also showed that the overall rate of adverse births for these data was 6%. These costs were also summarised by year in Figure 4.1.

Figure 4.1: Hospital costs per baby per year (2001-2012)

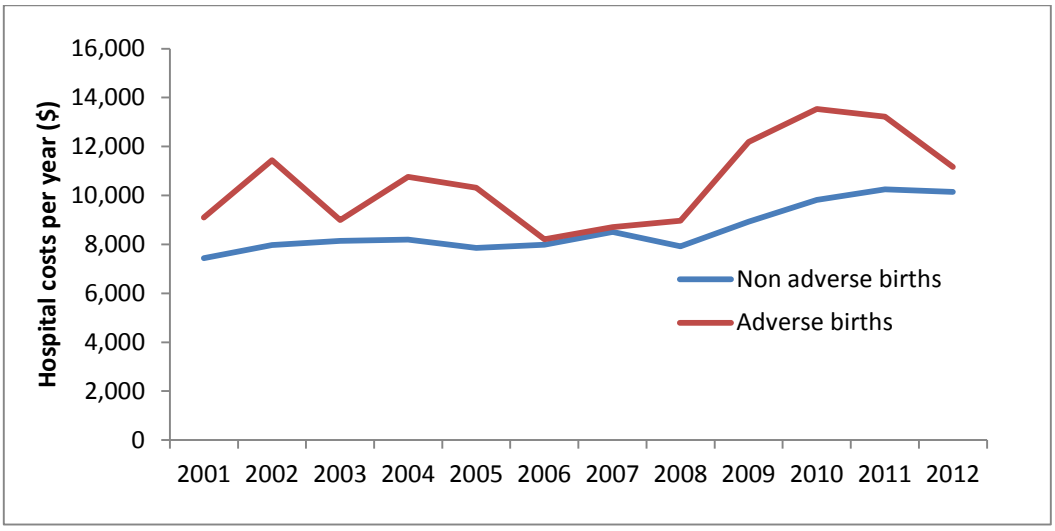


Figure 4.2: Adverse birth rate by year (2001-2012)

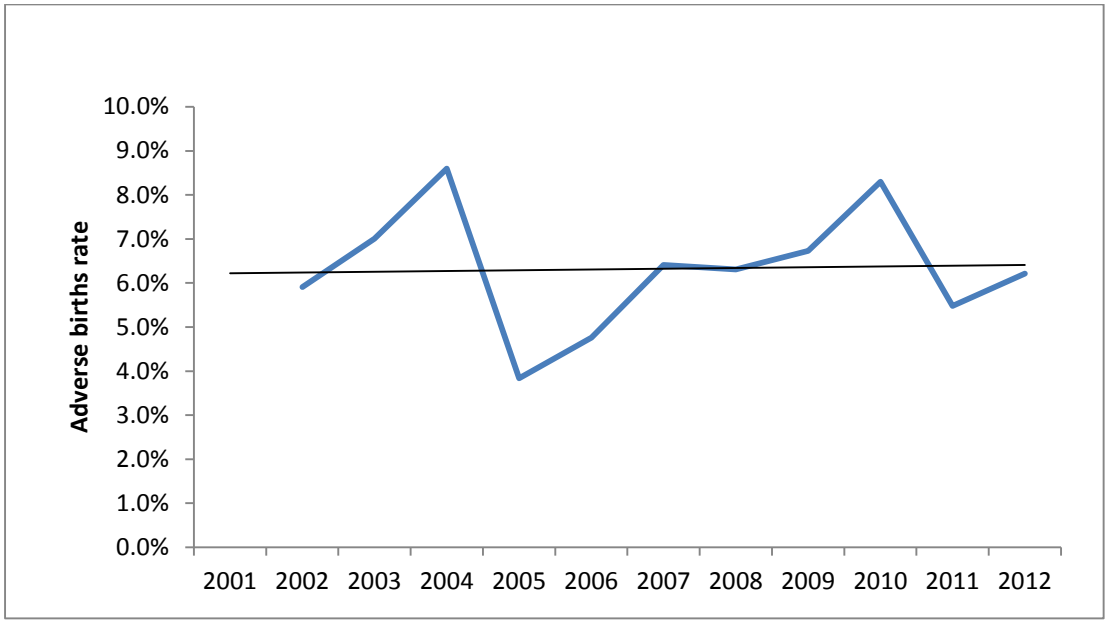
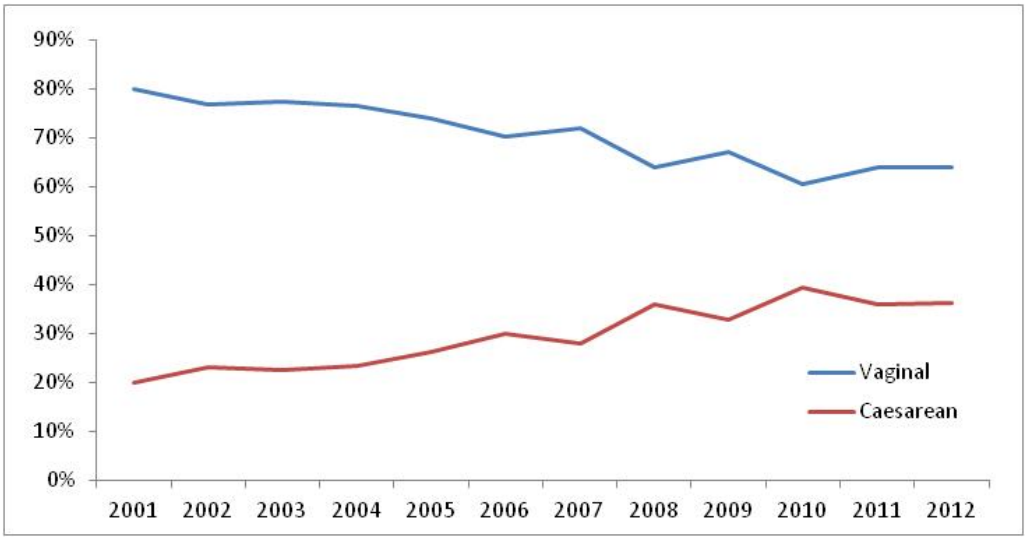


Figure 4.1 showed a clearly increasing trend in the cost from 2008 and slightly increasing prior to this for non-adverse births; similarly, the trend in costs for adverse births also appeared to be increasing; although given the relatively low numbers of adverse births, the cost data for this category were more volatile. The costs of adverse births were also higher than non-adverse births across all years. From Figure 4.2, the rate of adverse births was fairly volatile because of the low-prevalence nature of the condition but also showed a slight increasing tendency as well. There were a number of potential reasons explored for increasing costs. The first one was the notable rise in the proportion of caesarean deliveries over time (and correspondingly an offsetting decrease in the proportion of vaginal deliveries) and this is shown in Figure 4.3.

As caesarean deliveries cost substantially more than vaginal deliveries, this "change in the mix" by mode of delivery over time has driven some of the increase in overall cost. The reasons for increasing caesarean deliveries are still not well known (see Section 2.3.2) but a number of trends including higher maternal ages and increased artificial reproductive technology (ART) rates are likely to be contributing factors (Australian Institute of Health and Welfare, 2014a). Also, there was a notable issue with ALSWH survey data representing a cohort of women that age over time so any time-trend analysis must also take into account this ageing effect too. As increased maternal age has been associated with caesarean deliveries (Australian Institute of Health and Welfare, 2014a), the trend seen in Figure 4.3 may be exacerbated by this particular feature of the survey data. For this reason, these trends may not be indicative of overall population trends. However, these factors (that is, age and year) will be considered in more detail in the multivariate modelling in Section 4.3.2.3 as it is not possible to properly understand the complex interrelationships that exist

between them using simple multi-way tables or graphs. Multivariate analysis also has the advantage that it isolates the effect of the covariates while keeping all others constant (and this is not possible in simple multi-way tables, which aggregate over other factors). Of course, collinearity between covariate factors means that the concept of keeping factors constant may not reflect a realistic world condition, but it will assist in understanding the relative effects of factors on cost.

Figure 4.3: Mode of delivery by year (2001-2012)



4.3.1.2 Cost distributions

The next step was to analyse the cost distributions as a precursor to modelling. The cost distribution for the complete data was bimodal as shown in Figure 4.4.

Figure 4.4: Total maternal hospital cost distribution (untransformed)

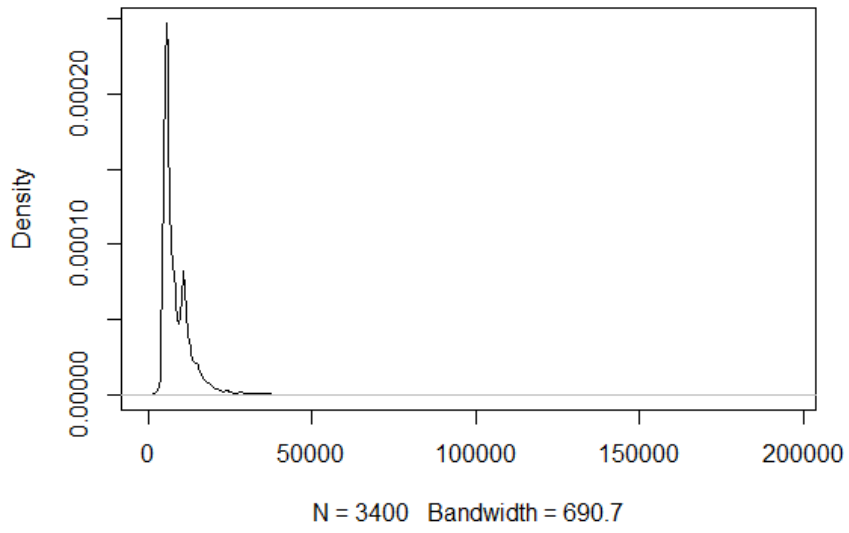
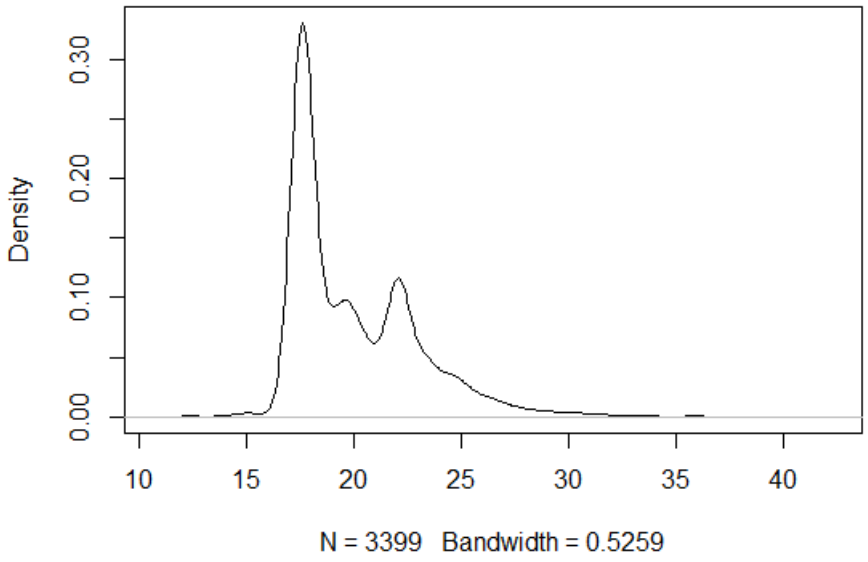


Figure 4.5: Total maternal hospital cost distribution (transformed, outlier removed)



There was one clear outlier associated with a woman with PPN 9006646 who had a total cost of $193,832.12. This case was investigated further and because the

excessive costs were the result of psychiatric services, this observation was removed from the analysis.

The two main modes visible in Figure 4.4 and Figure 4.5 related to vaginal deliveries (average cost approximately $5,500) and caesarean deliveries (average cost approximately $10,000), respectively. There was a suggestion of a third, middle mode in the transformed distribution that related to a more complicated vaginal delivery. As these modes were largely driven by the type of delivery and as AR-DRG codes were separated by type of hospital, the distributions were also considered separately by private and public patient status. Patient status was selected instead of hospital type because patient status is what determines the funding source for the cost – a public patient is funded by the government but private patients are not (regardless of which type of hospital they visit). For example, it is possible for patients to be treated in public hospitals as private patients, but they would have to fund this care themselves or through private health insurance; conversely, public patients may also be treated in private hospitals but this is rare.

Table 4.7 shows the proportion of records that fall under each combination of hospital type and patient status.

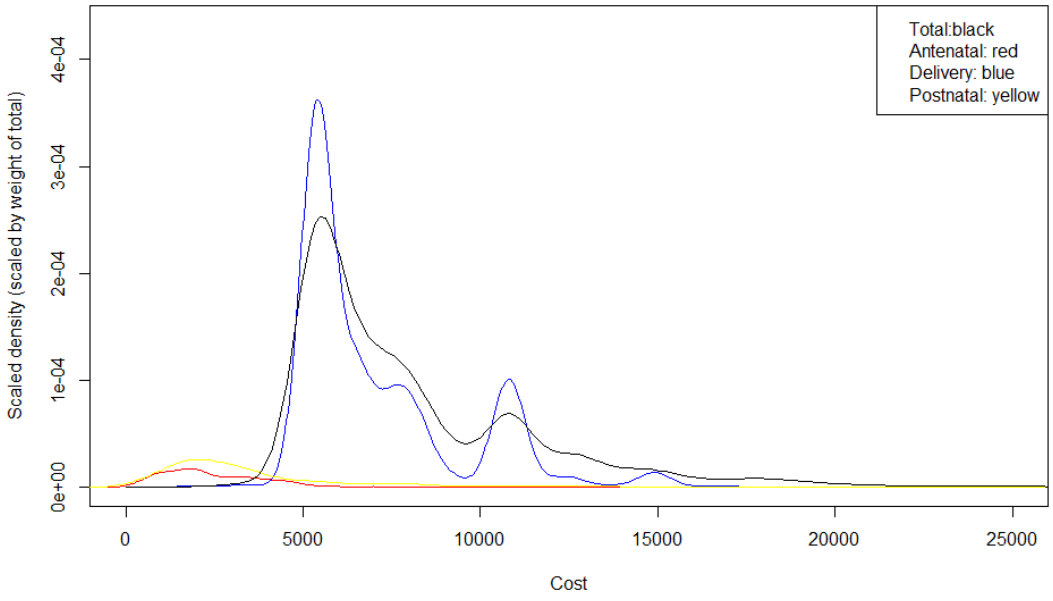
Table 4.7: Hospital type and patient status

Type of hospital	Type of patient	% records
Private	Private	31%
Private	Public	1%
Private	Other	1%
Public	Private	13%
Public	Public	54%
Public	Other	0%
% same hospital type/patient:		85%
% different hospital type/patient ("mixed"):		15%
% other:		1%

Table 4.7 showed that most public patients visited public hospital and private patients visited private hospitals. Furthermore, as a woman could have multiple hospital visits (in both public and private hospitals) as either a public or private patient, a determination of patient status by baby was necessary because the cost modelling was undertaken by baby. The allocation of public or private patient status was based on the most common patient status during the perinatal period. The need for such an allocation arose here for babies whose mothers had a "mixed" patient status; that is, they fell within the 15% of records reported in Table 4.7. Approximately 14% of the cases considered were "mixed" (this is slightly different to the 15% above as that represents the number of records as opposed to number of babies) but most had a majority private or public status so were allocated to the majority status. Around 4% of the cases were mixed equally between private and public patient status so the first half of these records were allocated to public status and the second half to private status. The allocation was chosen so that the data and

model results would be reproducible as a random allocation would prevent strict reproducibility. Nevertheless, as the order of cases itself may be considered a random ordering (that is, it has no underlying structural rationale), this choice should not introduce any systematic effects to the analysis. The “equal mix” status represents less than 5% of the total cost in any event, so any allocation effects represent an immaterial proportion of the total cost. Given this new definition of patient status for each baby, the cost distributions by patient status were as follows in Figure 4.6 and Figure 4.7.

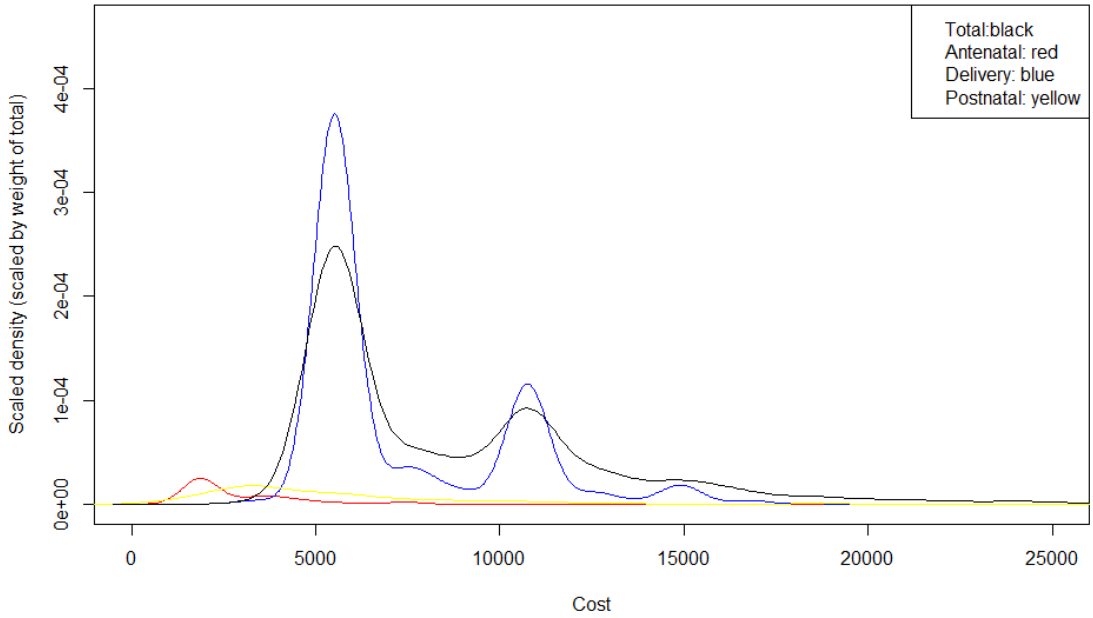
Figure 4.6: Private patient cost distribution



The distributions for each period were scaled by the weight that they each represented of the total cost. Note that as these are cost *distributions*, it is reasonable for the modes of the total distribution to have lower peaks than the sum of the individual component distributions.

A tri-modal cost distribution was evident for private patients, and the three modes related to uncomplicated vaginal deliveries, complicated vaginal deliveries, and caesarean deliveries, respectively.

Figure 4.7: Public patient cost distribution



By way of contrast, the cost distribution for public patients seemed closer to a bi-modal distribution, with the two modes identified with vaginal deliveries and caesarean deliveries. Nevertheless, there is some evidence of a third mode for complicated vaginal deliveries in the delivery cost distribution.

Despite the multiple modes, the data were not segmented any further than private and public patient status. This segmentation was consistent with the focus of this thesis on public costs, meaning that these patients needed to be considered separately. Note that it was not possible to segment the data by mode of delivery as this only related to the particular hospital visit for the delivery of the baby.

4.3.2 Classification and Regression Trees (CART)

Given the results of the exploratory analysis, in particular the observed distributions for public and private costs, data were considered separately for public and private cases. All the years available in the data were used for both the CART and GLMs.

Regression tree models were fit relating costs during each period to all covariates available for modelling. A complete list of possible covariates is in Appendix A and key factors were discussed in Section 3.3.3 under the broad categories of health service use, obstetric factors, reproductive factors, demographic factors, health behaviours and psychological and physical health factors. For reference purposes, the complete set of variables selected from CART is shown in Appendix B but simplified versions of the trees are shown graphically here and Table 4.8 below provides more information on the most important selected factors shown in these trees (including a description of the label as some have cut-off in the diagrams).

Table 4.8: Hospital costing - key CART factors

Tree label	Description	Label
deliv	Mode of delivery	1= Normal vaginal 2= Forceps 3= Vacuum extraction 4= Vaginal breech 5= Caesarean section 9= Not stated
hospoth2	Have you been admitted to hospital in the last 12 months for reasons other than pregnancy?	1= Yes 0= No (from coding)
model of	Model of care factors include: Model of care-antenatal - general practioner	1=Yes 0=No Mss=Missing

	Model of care-antenatal - hospital based medical Model of care-antenatal - independent midwife Model of care-antenatal - hospital based midwife Model of care-antenatal - not applicable Model of care-antenatal - private obstetrician Model of care-birth - general practioner Model of care-birth - hospital based medical Model of care-birth - independent midwife Model of care-birth - hospital based midwife Model of care-birth - not applicable Model of care-birth - private obstetrician	
Birth.we	Birthweight of baby	Continuous
metsmins	Exercise score	Continuous (higher score indicates more exercise)
estimate	Estimated gestational age	Weeks
Intanx2	In the last 12 months, have you had any of the following: Episodes of intense anxiety (eg panic attacks)	1= Never (No) 2= Rarely 3= Sometimes 4= Often
Induction	Induction of baby	1= Yes 0= No
seifaadv	Socio-economic index for areas (SEIFA) Index Socio-economic Advantage/Disadvantage	Continuous (higher score indicates more advantage)

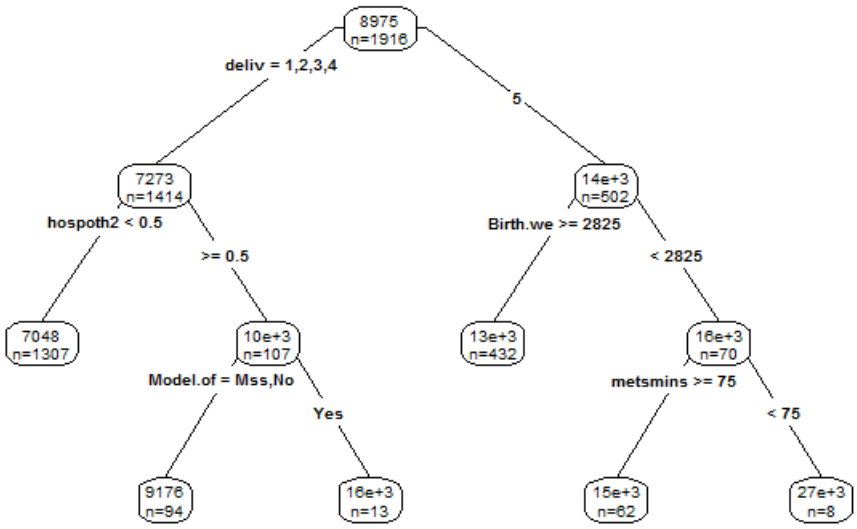
Cancer5	Have you ever been told by a doctor that you have: Cancer	1= Yes 0= No
Any.smok	Any smoking during pregnancy?	1= Yes 0= No
Resuscit	Resuscitation of baby	1= Yes 0= No
hgt	Height of mother	Continuous
Mother.s	Mother's age	Years
Infertil	Have you and your partner (current or previous) ever had problems with infertility (that is, tried unsuccessfully to get pregnant for 12 months or more)?	1= Never tried to get pregnant 2= No problem with infertility 3= Yes, but have not sought help/treatment 4= Yes, and have sought help/treatment"
Patient2	Patient status	Private=Private patient Public=Public patient Mixed=Mixed private / public Other=Other
Exercise	Exercise group	"1= 'Nil/sedentary' 2= 'Low' 3= 'Moderate' 4= 'High'"
occupati	We would like to know your main occupation now:	1= Manager or administrator 2= Professional 3= Associate professional 4= Tradesperson or related worker 5= Advanced clerical or service worker

		6= Intermediate clerical, sales/service worker 7= Intermediate production or transport worker 8= Elementary clerical, sales or service worker 9= Labourer or related worker 10= No paid job
Hrswork	Hours worked	1= 1-15 hrs 2= 16-24 hrs 3= 25-34 hrs 4= 35-40 hrs 5= 41-48 hrs 6= 49+ hrs 7= not in labour force / unemployed
Marijuana	Have you used it in the last 12 months? Marijuana (cannabis, hash, grass, dope, pot, yandi)	1= Yes 0= No
Lotr	The 6-item sum is referred to as the Revised Life Orientation Test (LOT-R) score. Higher scores indicate a more optimistic outlook.	1= Strongly disagree 2= Disagree 3= Neutral 4= Agree 5= Strongly agree
Pain_ga2	Analgesia for delivery - General anaesthetic	1= Yes 0= No

4.3.2.1 Public CART results

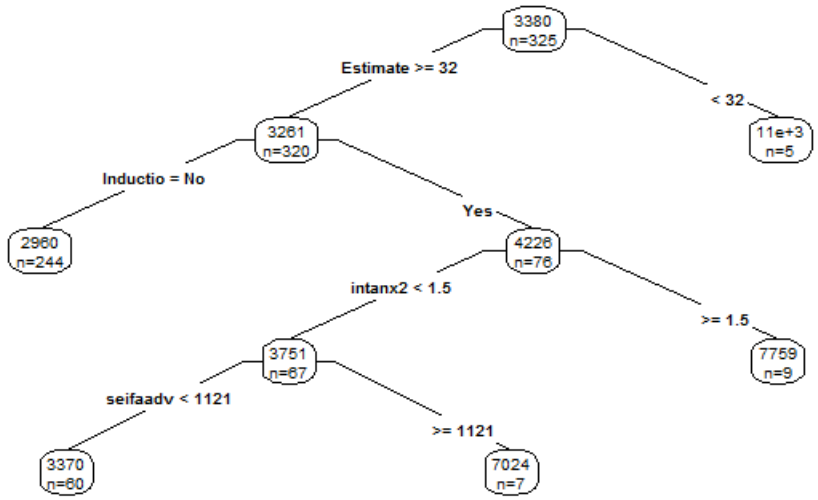
The regression tree model for total public costs (Figure 4.8) selected mode of delivery (*deliv)* as the first variable to split the tree and predicted that women who had vaginal deliveries had a lower average cost than women who had caesareans. This result made sense intuitively, as caesareans are more costly procedures than vaginal deliveries (Independent Hospital Pricing Authority, 2015) and correspond to the highest mode in cost distributions for all categories. Considering further splits lower in the tree model, women who had caesareans and babies born less than 2.8kg (*Birth.we*) were predicted to be in a higher cost category while women who had vaginal deliveries and did not have hospital visits for reasons other than pregnancy (*hospoth2)* were in a lower-cost category. Note that low birthweight was a category of adverse births; however, the cut-off selected for the continuous variable birthweight within the regression tree fitting algorithm was much higher than the cut-off used in the definition used for adverse births (2.5kg). This suggested that the cut-off for birthweight used in the normal definition of adverse births in the original categorisation may be too low when looking at the impact of birthweight on antenatal maternal cost. Finally, the model of care factor identified in the lowest part of the tree related to care with a private obstetrician (*Model.of*) with takeup of such care resulting in higher costs.

Figure 4.8: Public Total CART results



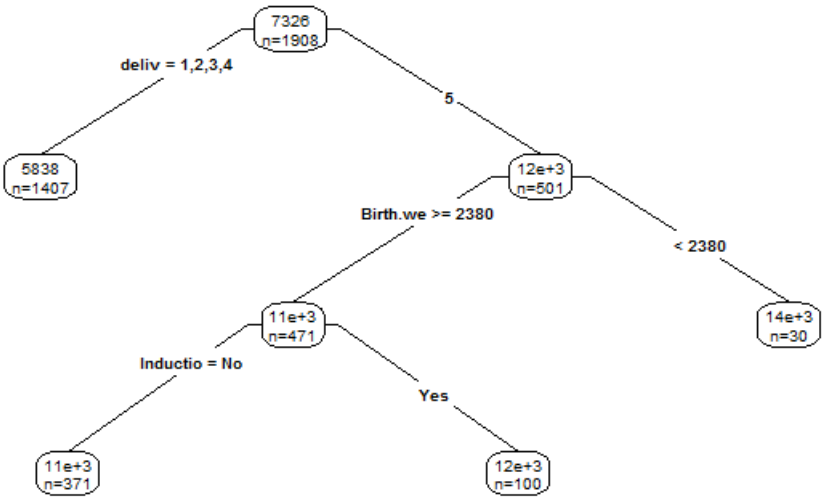
There was very little data contributing to the antenatal regression tree model (Figure 4.9), making most of the splits difficult to interpret because of the variability in fit that is often encountered in regression tree modelling, particularly when data is sparse. The first split of the antenatal regression tree related to an adverse birth category, namely premature birth, with the model predicting the cost of cases involving very premature babies (that is, estimated gestational age less than 32 weeks) to be almost triple the cost of cases for which babies were born after 32 weeks gestation. However, the data set only contains five records of such very premature babies so this result should be interpreted with considerable caution. Intense anxiety (*intanx2*) was another notable split with women with worse self-reported mental health having higher predicted costs.

Figure 4.9: Public Antenatal CART results



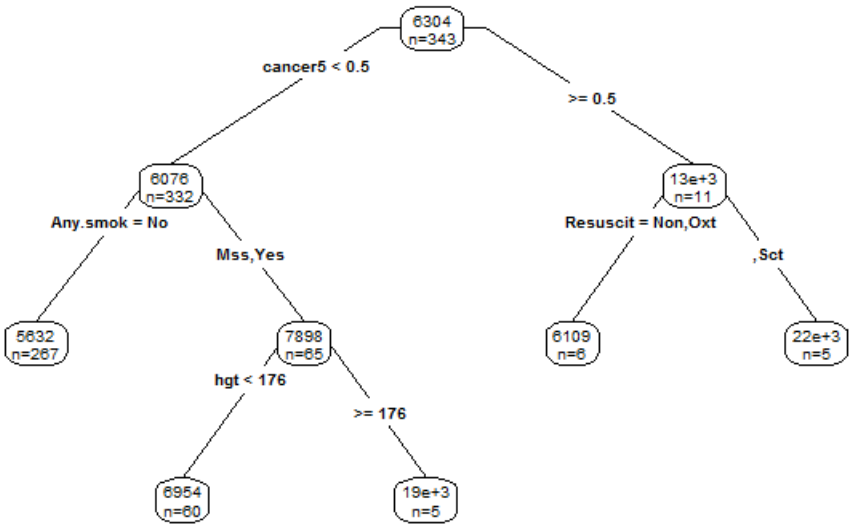
For delivery costs (Figure 4.10), mode of delivery was the most important predictor, reflecting the first split of the tree; with the same split of vaginal and caesarean deliveries as in the total model. As stated previously, this split makes sense as caesareans are more costly than vaginal deliveries. The next split relates to the birthweight of the baby and this split is only applied to the node of the caesarean sub-branch of the tree. The cut-off chosen by the regression tree algorithm for the continuous variable birthweight is 2.4kg, which is just under the cut-off typically used to define low birthweight (2.5kg) for the purpose of declaring an adverse-birth event.

Figure 4.10: Public Delivery CART results



There was very little data contributing to the postnatal regression tree model Figure 4.11, making most of the splits difficult to interpret because of the variability in fit that is often encountered in regression tree modelling. However, the first split was based on whether the woman had cancer or not (*cancer5)*. In cases for which a woman has not had cancer, whether she smoked or not (*Any.smok)* was the differentiator of cost, with smokers having a higher predicted cost than non-smokers. Again, results must be interpreted with caution, and these outcomes were regarded as indicative rather than prescriptive as part of an exploratory analysis prior to more formal analyses using generalised linear models.

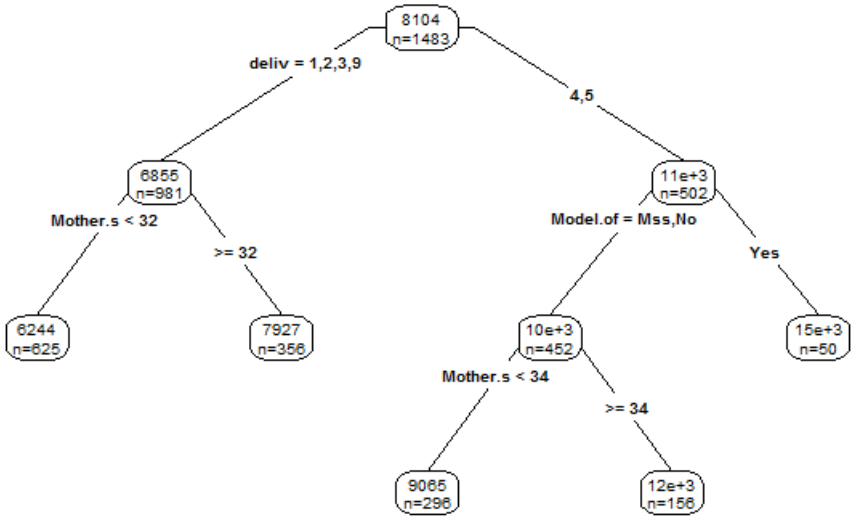
Figure 4.11: Public Postnatal CART results



4.3.2.2 Private CART results

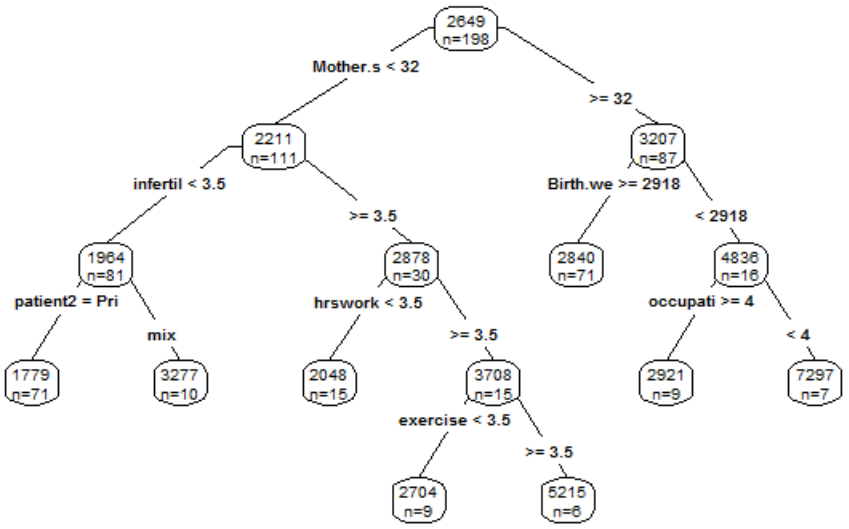
The regression tree selected mode of delivery as the primary split for the private total tree model (Figure 4.12) and predicted that women who had vaginal, forceps and vacuum extraction deliveries (herein labelled “low risk deliveries”) to have a lower predicted cost than women who have had caesareans or breech deliveries (herein labelled “high risk deliveries”). As stated previously, this grouping makes sense as caesareans are more costly than vaginal deliveries. Furthermore, women with low risk deliveries aged less than 32 (*Mother.s*) were predicted to fall into a lower cost category while women who had higher risk deliveries and gone through a hospital-based medical model of care were predicted to incur higher cost.

Figure 4.12: Private Total CART results



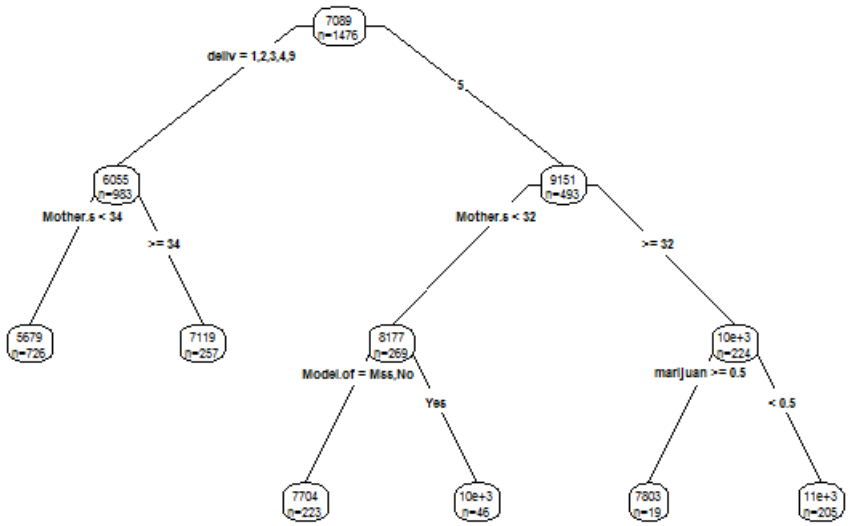
For antenatal costs (Figure 4.13), maternal age was the primary split of the tree, with the same cut-off age used for the split (age 32) selected in this case as within the total model. Furthermore, women aged younger than 32 who had problems with infertility (*infertil)* and have not sought help/treatment for infertility were predicted to be in a lower cost category while women aged over 32 that had a baby with birthweight less than 2.9kg were predicted to be in a higher cost category. Note that there was a similar finding in the "total public" cost model with this weight cut-off and similar comments apply here.

Figure 4.13: Private Antenatal CART results



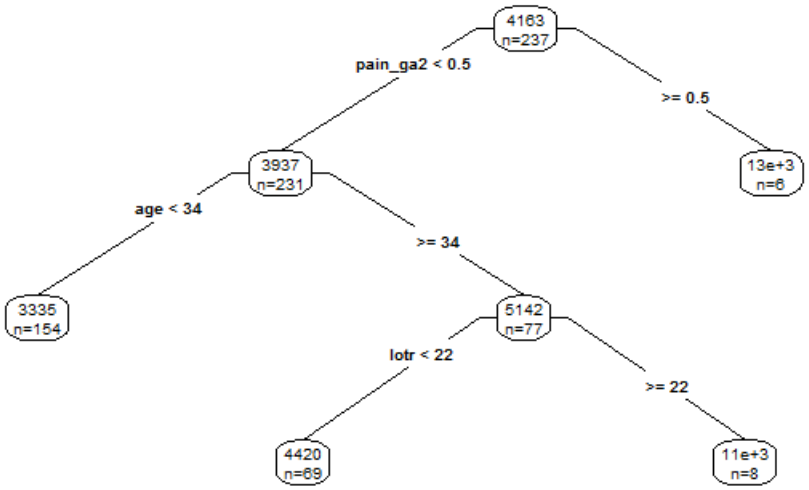
For delivery costs (Figure 4.14), mode of delivery was the primary split of the tree; however, the groups were caesarean deliveries and all vaginal deliveries (both complicated and not), an outcome that was slightly different to the total model. This split makes sense intuitively as caesareans are much more costly than vaginal deliveries, with or without complications. The next most important split was maternal age, with women aged over 32 who had caesarean's predicted as higher cost and women aged under 34 with vaginal deliveries predicted as lower cost.

Figure 4.14: Private Delivery CART results



There was very little data contributing to the postnatal regression tree model (Figure 4.15), making most of the splits difficult to interpret as for the public antenatal and postnatal case. The first split was based on whether there was pain relief in the form of general anaesthesia (*pain_ga2)* used in the delivery of the baby, however, corresponding to only 6 records. When this variable was removed (on the basis that it exhibited almost no variability) and the regression tree was re-fit, then mode of delivery was the primary split with caesareans and vaginal deliveries with forceps in the higher cost category.

Figure 4.15: Private Postnatal CART results



4.3.2.3 Summary of CART results

Given the results of the CART modelling above (and additional factors identified in the literature review in Chapter 2), Table 4.9 summarises all the factors that were selected for inclusion in the formal parametric modelling phase. Note that the modelling process used to test these factors was described earlier in Section 3.6.3.

Table 4.9: Factors tested in GLM's (hospital costing)

Factors	**Category**
Maternal age	Demographic
SEIFA indices	Demographic
Hours worked	Demographic
Occupation	Demographic
Rural, remote and metropolitan areas (RRMA) classification	Demographic
Aria+ group (area of residence)	Demographic
Marital status	Demographic
Education	Demographic

Income	Demographic
Alcohol pattern	Health behaviour
Smoking status	Health behaviour
Exercise	Health behaviour
Marijuana	Health behaviour
BMI	Health behaviour
Partner violence	Health behaviour
Drug use	Health behaviour
Patient status	Health service use
Hospital visit for reasons other than pregnancy	Health service use
Access to GP that bulk bills	Health service use
Access to after-hours medical	Health service use
Access to female GP	Health service use
Specialist use	Health service use
GP consultations	Health service use
Private health insurance status - hospital cover	Health service use
Private health insurance status - ancillary cover	Health service use
Birth weight	Obstetric
Mode of delivery	Obstetric
Model of care factors	Obstetric
Resuscitation of baby	Obstetric
Labour onset	Obstetric
Pain relief factors	Obstetric
Gestational age	Obstetric
Weeks pregnant at first antenatal visit	Obstetric
Apgar score at 5 minutes	Obstetric
Main indication for caesarean section	Obstetric
Pain relief - general anaesthesia	Obstetric
Induction of labour	Obstetric

Postnatal depression	Psychological and physical health
Depression scale (cesd10)	Psychological and physical health
Life outlook index (lotr)	Psychological and physical health
Social support indices (MOS)	Psychological and physical health
Urinary Tract Infection	Psychological and physical health
Emotional abuse	Psychological and physical health
Cancer	Psychological and physical health
Intense anxiety	Psychological and physical health
Stress	Psychological and physical health
Endometrioses	Psychological and physical health
Diabetes (type1, type2)	Psychological and physical health
Hypertension	Psychological and physical health
Anxiety	Psychological and physical health
Stress about own health	Psychological and physical health
Gestational diabetes	Psychological and physical health
Asthma	Psychological and physical health

Antenatal anxiety	Psychological and physical health
Antenatal depression	Psychological and physical health
Postnatal anxiety	Psychological and physical health
Antenatal depression	Psychological and physical health
IVF	Reproductive
Infertility	Reproductive
Number of previous pregnancies	Reproductive
Number of births	Reproductive
Adverse birth	Reproductive
Previous adverse birth	Reproductive
Previous stillbirth	Reproductive
Previous premature birth	Reproductive
Previous low birth weight birth	Reproductive
Terminations (abortions)	Reproductive
Stillbirth	Reproductive
Premature birth	Reproductive
Low birth weight birth	Reproductive
Neonatal death	Reproductive
Congenital condition	Reproductive
Height	Other
Baby's place of birth	Other

4.3.3 Total cost GLMs

The regression tree models provided valuable guidance as to an initial set of variables to include as part of a model selection process for familiar parametric models for cost. Using the factors selected in the CART models, generalised linear

models relating cost and the other covariates within the data were fit, assuming a Gamma error distribution and log link. Results reported at the significance level less than 0.1% are shown below and discussed briefly but more in-depth discussions are in Section 4.4. This significance level was selected due to the large volume of variables being analysed and the aim of producing parsimonious models. Model checks including a model refit using a different error distribution and backward stepwise selection methods for significance of factors are included in Appendix C for some models. These checks showed that the significance levels were appropriate and the methods adopted were robust to these changes.

4.3.3.1 Public GLM results

Table 4.10 shows intense anxiety was the only factor significant at the 1% significance level for the antenatal period. It was also identified in the equivalent regression tree.

Table 4.10: Public Antenatal GLM results

Coefficients	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	7.832	0.0873	89.76	6.22e-229 (= 0)
intanx2	0.206	0.0594	3.48	5.79e-04

Table 4.11 shows the public delivery results and mode of delivery was found to be a highly significant factor, particularly the category for caesarean deliveries (*deliv5*). Adverse births *(ab)* were also found to be a significant factor and both adverse births and, correspondingly, mode of delivery were seen as important in the equivalent regression tree. The other interesting significant factors were smoking status (*smokst)*, diabetes (*maternal.diabetes.mellitus*), labour onset *(labour.onset)*, private

health insurance (*prihealth*) and baby's place of birth (*baby.s.place.of.birth*). The private health insurance finding is interesting as this suggests that those that elect to use public services even if they have private health insurance are associated with higher costs compared with those that do not have private health insurance. The place of birth factor really differentiates the cost between whether the baby was born in hospital or not, but as it was a nuisance factor (as approximately 95% of the babies were born in hospital) models were refit with this factor as a random effect for parsimony – the resultant models fall into the class of generalised linear mixed models (GLMM) (see Section 4.3.4). The four levels of this factor were "Birth Centre" (at base level), "Born before arrival", "Hospital" and "Planned Birth Centre / Hospital Admission". The base level of the labour onset factor was "Induction", so estimated effects are to be interpreted as differential to this baseline.

Table 4.11: Public Delivery GLM results

Coefficients	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	8.640	0.024	365.42	0.00e+00
deliv2	0.094	0.025	3.72	2.05e-04
deliv3	0.041	0.018	2.29	2.21e-02
deliv4	0.081	0.054	1.49	1.37e-01
deliv5	0.688	0.013	51.12	0.00e+00
Labour.onsetNo labour	-0.042	0.017	-2.46	1.39e-02
Labour.onsetSpontaneous	-0.012	0.010	-1.20	2.30e-01
Prihealth	0.023	0.009	3.08	2.14e-03
Smokst	0.012	0.004	3.05	2.36e-03
Baby.s.place.of.birthBorn before arrival	-0.201	0.051	-3.92	9.31e-05
Baby.s.place.of.birthHospital	0.019	0.020	0.98	3.29e-01
Baby.s.place.of.birthPlanned BC/hosp adm	-0.010	0.039	-0.26	7.93e-01
Ariapgp	-0.011	0.005	-2.27	2.31e-02
Maternal.diabetes.mellitus.Yes	0.108	0.043	2.50	1.26e-02
Ab	0.077	0.017	4.65	3.62e-06

Cancer (*cancer5)* was the only factor significant in the postnatal model (Table 4.12) and it must be kept in mind that postnatal costs represented only 11% of total costs. A simple one-way analysis of cancer patients in the antenatal period showed that they cost 22% more than non-cancer patients, and this was largely due to more frequent hospital visits. Note that cancer was also the primary split in the corresponding regression tree and showed that only 11 women had cancer so these results should be interpreted with caution given the low volume of data.

Table 4.12: Public Postnatal GLM results

Coefficients	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	8.351	0.033	254.02	0.00000
cancer5	0.478	0.153	3.13	0.00186

As the delivery model dominated the total model, the total results (Table 4.13) were very similar to the results for the delivery period.

Table 4.13: Public Total GLM results

Coefficients	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	9.418	0.145	65.04	0.00e+00
deliv2	0.104	0.075	1.40	1.62e-01
deliv3	0.185	0.056	3.31	9.76e-04
deliv4	0.231	0.174	1.33	1.84e-01
deliv5	0.654	0.040	16.17	5.25e-53
Smokst	0.049	0.013	3.73	2.03e-04
Ivf	-0.300	0.072	-4.16	3.41e-05
Labour.onsetNo labour	-0.121	0.051	-2.40	1.66e-02
Labour.onsetSpontaneous	-0.133	0.031	-4.25	2.33e-05
Prihealth	0.112	0.026	4.27	2.10e-05
cancer5	0.500	0.088	5.68	1.71e-08

4.3.3.2 Private GLM results

Estimated gestational age (*Estimated.gestational.age..wks*) was the only significant factor in the private antenatal model (Table 4.14) and the coefficient estimate shows that the longer the gestational age, the lower the cost. This makes sense as it can be

reasoned that prematurity may be linked with a more complex and therefore potentially more costly pregnancy. On the other hand, a pregnancy that goes closer to full-term may be more likely to be less complicated and therefore less costly.

Table 4.14: Private Antenatal GLM results

Coefficients	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	11.383	0.895	12.72	1.98e-27
Estimated.gestational.age..wks.	-0.091	0.023	-3.93	1.20e-04

Table 4.15 shows the results for the private delivery models and they were similar to the public delivery model, although with some interesting differences. A private obstetrician's model of care (*Model.of.care.antenatal...private.obstetrician*), age (*age)* and IVF (*ivf)* had significant impacts on cost, but factors such as smoking status, diabetes and adverse births did not appear to contribute overtly to cost, perhaps because the other factors were swamping their effects. It was difficult to understand why a model of care without an obstetrician was predicted to be *more* costly than one with an obstetrician, but it might be due to better quality of care and therefore better outcomes and consequently lower health system costs from the improved outcomes. Age was found to be important in many of the private regression trees the significance here is not surprising, but it was interesting that it was not a feature of the public models. The impact of IVF during delivery was validated by research that showed that women who used ART were more likely to have caesarean deliveries (Macaldowie et al., 2012) so will therefore be more costly in this period. Furthermore, a closer analysis of the data revealed that 45% of women who used IVF had caesarean deliveries compared to 32% of women who did not use

IVF. Finally, whether private health insurance was used was not significant, but it was for the public model. This phenomenon is most likely because most of the patients in this category had private insurance (as they are private patients).

Table 4.15: Private Delivery GLM results

Coefficients	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	7.729	0.123	62.85	0.00E+00
Baby.s.place.of.birthBorn before arrival	-0.243	0.101	-2.41	1.62E-02
Baby.s.place.of.birthHospital	0.055	0.054	1.01	3.14E-01
Baby.s.place.of.birthPlanned BC/hosp adm	-0.001	0.100	-0.01	9.90E-01
Baby.s.place.of.birthPlanned homebirth	-0.214	0.228	-0.94	3.49E-01
deliv2	0.012	0.031	0.40	6.92E-01
deliv3	0.028	0.024	1.17	2.40E-01
deliv4	0.180	0.132	1.37	1.72E-01
deliv5	0.395	0.014	27.53	4.87E-129
Model.of.care.antenatal...private. obstetricianNo	0.081	0.026	3.14	1.76E-03
Model.of.care.antenatal...private. obstetricianYes	0.062	0.018	3.41	6.80E-04
Ivf	-0.077	0.029	-2.63	8.68E-03
Age	0.032	0.003	11.56	2.38E-29

Pain relief using general anaesthesia (*pain_ga2*) and age were the only significant factors for the postnatal model (Table 4.16), again recognising the small relative contribution to overall cost made during the postnatal period. For the first factor, the

possibility was that the anaesthesia was used for a complication following delivery which required a more expensive episode of care, resulting in higher postnatal costs. This factor was also the primary split of the corresponding regression tree.

Table 4.16: Private Postnatal GLM results

Coefficients	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	6.3612	0.4722	13.47	6.84E-32
pain_ga2	1.1292	0.3207	3.52	5.06E-04
Age	0.0557	0.0147	3.79	1.86E-04

As seen in the public models, the total model (Table 4.17) most closely resembles the delivery model as delivery dominated the cost. However, the model of care and baby's place of birth factor from the delivery model were not significant.

Table 4.17: Private Total GLM results

Coefficients	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	8.555	0.192	44.53	3.33E-255
deliv2	0.048	0.054	0.89	3.74E-01
deliv3	-0.002	0.041	-0.05	9.63E-01
deliv4	0.300	0.227	1.32	1.86E-01
deliv5	0.396	0.025	15.93	6.72E-52
Age	0.037	0.005	8.12	1.20E-15
Ivf	-0.329	0.052	-6.34	3.22E-10
patient2Pri	-0.274	0.064	-4.31	1.78E-05

4.3.4 GLMMs

As discussed above, baby's place of birth was found to be a significant factor in some of the preceding models, but as this was a nuisance factor and really only differentiating between whether the baby was born in the hospital or outside the hospital, the models were re-fit using this factor as a random effect. This approach ensured the model was more parsimonious, allowing for variability in birth location without the necessity to estimate multiple additional parameters. Additional random effects were also explored where appropriate.

Table 4.18 compares the significant factors for the GLMs and GLMMs. The complete GLMM output is shown in Appendix D for delivery models only as they are the most important in this study and also the models where the random effects had the most impact (as seen in Table 4.18).

Table 4.18: Comparison of GLM and GLMM results

Model	GLM	GLM + 1 RE	GLM + many RE[12]
Private antenatal	Gestational age	As for GLM	As for GLM
Private delivery	Mode of delivery Model of care – private obstetrician Ivf Baby's place of birth Age	Mode of delivery Model of care – private obstetrician Ivf Age	As for GLM
Private post	Pain relief – general anaesthesia Age	As for GLM	As for GLM
Private total	Mode of delivery Ivf Patient status Age	As for GLM	As for GLM
Public antenatal	Intense anxiety	As for GLM	As for GLM
Public delivery	Mode of delivery Labour.onset Prihealth Smokst ab Area Diabetes Baby's place of birth	Mode of delivery Labour.onset Prihealth Smokst ab Area Diabetes	Mode of delivery Labour.onset Prihealth Smokst ab Diabetes
Public post	Cancer5	As for GLM	As for GLM
Public total	Mode of delivery Smokst Ivf Labour.onset Prihealth Cancer5	As for GLM	As for GLM

[12] Random effects included baby's place of birth, local health district of hospital, hospital obstetric level, health area of hospital, and hospital.

4.3.5 Interactions

All possible combinations of two-way interactions were tested in the final mixed models but none were found to be significant.

4.3.6 Frequency and severity GLMs

As described in Chapter 3, Section 3.6.1 it was useful to consider the cost data by frequency and severity of the cost to further understand the underlying drivers of this cost. The frequency and severity were defined as follows:

Frequency = number of services

Severity = average cost of the service = total cost / number of services

A similar process to the total modelling was adopted using regression trees to identify factors and then GLMs and GLMMs to model the cost. The GLMs are discussed in more detail below with mixed effects where relevant for delivery severity models only. This was because the antenatal and postnatal models were not as important for the hospital costing and the sparse data in these sub-periods made the breakdown into frequency and severity less useful. Furthermore, only severity modelling produced significant results because the frequency of visits during the short time-span of the delivery period usually only related to the one visit for the actual delivery of the baby. Therefore, frequency models were not used and severity models largely resembled the total cost delivery models. Given these comments, the results of the GLMMs for severity models only are shown in Appendix E with results of GLMs for severity modelling for public and private discussed below.

4.3.6.1 Public frequency and severity models

As discussed above, there were no significant factors in the frequency model, a result that made sense because the delivery period only represented the ten days prior to and including the date of birth of the baby. Therefore, it was highly likely that there was only one hospital visit during this time for most women. Correspondingly, one might expect that the main drivers of total cost would come from the factors that impact on the severity of the episode of care. The severity model (Table 4.19), therefore had very similar features to the total cost model for delivery, albeit with a number of factors no longer significant (adverse births, area, smoking status and labour onset). Therefore, diabetes and mode of delivery were factors driving the costs in this particular model as these factors were associated with higher average costs. The GLMM also produced similar output when baby's place of birth was included as a random effect.

Table 4.19: Public delivery severity GLM results

Coefficients	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	8.603	0.018	474.49	0.00E+00
deliv2	0.005	0.024	0.19	8.52E-01
deliv3	0.032	0.018	1.80	7.25E-02
deliv4	0.096	0.059	1.63	1.03E-01
deliv5	0.663	0.009	70.35	0.00E+00
Maternal.diabetes.mellitus.Yes	0.152	0.044	3.43	6.14E-04
Baby.s.place.of.birthBorn	-0.231	0.050	-4.59	4.65E-06
Baby.s.place.of.birthHospital	-0.001	0.019	-0.05	9.57E-01
Baby.s.place.of.birthPlanned	-0.020	0.037	-0.55	5.83E-01

4.3.6.2 Private frequency and severity models

As for the public model, there were no significant factors in the frequency model (most likely again because of the short period covered under the delivery period resulting in only one hospital visit) and the severity model (Table 4.20) had very similar features to the total cost model for delivery, but with two factors omitted as they were no longer significant (IVF and model of care for private obstetrician). Therefore, age and mode of delivery were driving the costs in this particular model as these factors were associated with higher average costs. The GLMM showed that the significant factors remained the same when baby's place of birth was included as a random effect.

Table 4.20: Private delivery severity GLM results

Coefficients	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	7.574	0.073	103.67	0.00E+00
deliv2	0.024	0.026	0.93	3.52E-01
deliv3	0.022	0.020	1.12	2.64E-01
deliv4	-0.169	0.126	-1.35	1.78E-01
deliv5	0.404	0.013	32.23	1.11E-172
deliv9	0.199	0.214	0.93	3.53E-01
Age	0.029	0.002	16.91	1.05E-58
Baby.s.place.of.birthBorn before arrival	-0.302	0.086	-3.50	4.73E-04
Baby.s.place.of.birthHospital	0.157	0.047	3.32	9.14E-04
Baby.s.place.of.birthPlanned BC/hosp adm	0.061	0.082	0.75	4.56E-01
Baby.s.place.of.birthPlanned homebirth	-0.038	0.218	-0.18	8.61E-01

4.4 Discussion

As delivery costs represented over 80% of the total hospital cost, it was no surprise that these models were strongly consistent with the models for total cost and this discussion will focus on the findings in these models. The antenatal and postnatal models had few factors of significance that were common to both public and private models but these periods reflected only relatively small contributions to total cost, and the factors found to be significant to these smaller cost elements were rather variable as a result.

The mode of delivery was clearly the most significant factor in both public and private delivery models. This finding made sense intuitively as there are clear differences in the cost structures of caesareans versus vaginal deliveries in the Australian hospital system, and this is what drove the cost differential for the majority of the cases. Furthermore, as caesarean deliveries cost almost double vaginal deliveries and represented an increasing proportion of all deliveries within the NSW (and Australian) experience, they will have a significant impact on the cost. The increases in the rate of caesarean deliveries in recent years (a phenomenon which carries a number of risk factors in and of itself, (Australian Institute of Health and Welfare, 2014a) has had a material impact on the increase in maternal costs overall. The underlying risk factors of caesareans are still not well known (Australian Institute of Health and Welfare, 2014a) but are relevant here to the extent that they explain why a caesarean has occurred, and henceforth the impact on cost.

The link between adverse births and maternal health system costs was also evident in the public delivery model where adverse births were identified as a significant factor. The birthweight of the baby was also a significant factor identified in the regression

tree modelling. This finding suggested that the hospital costs of the woman were related to the birth outcome of the baby but principally only at the time of delivery. In contrast, for the private delivery model, adverse births were not a significant factor, a result which was also consistent with the regression tree modelling outcomes. It is difficult to explain exactly why this might be the case, however, the overall rates of adverse births were lower for private patients compared with public patients (5.2% for private patients compared with 6.7% for public patients) suggesting private patients were less likely to experience adverse birth outcomes and therefore they had a lower impact on the maternal cost. This finding is also consistent with research using national perinatal data over the period 2001-2004 that showed the prevalence of adverse perinatal outcomes was higher in public hospitals compared to private hospitals after adjusting for numerous demographic factors and method of birth (Robson, Laws, & Sullivan, 2009). This could also be explained by "high risk" women being transferred from the private system to the public system. This finding, and in particular a more detailed investigation on the demographics of women with private health insurance should be investigated further. Finally, antenatal and postnatal costs were a small proportion of the total hospital cost but there was no significant relationship between the birth outcome of the baby and the maternal costs in these periods for both public and private.

Place of birth of the baby was also a significant factor in both the public and private models, but this feature was essentially nuisance (in a statistical sense – that is, the estimates themselves were not of primary interest). Thus, this feature was more appropriately handled as a random effect within the modelling as it really only differentiated between whether the baby was born in a hospital or not.

The final few significant factors for the private model were IVF, age and the antenatal model of care for private obstetrician, which were not found significant in the equivalent public model. Age was consistently selected as important in private regression trees, and these results showed that it was a more important issue for private compared to public, possibly because private attracts a certain age group of women. Further analysis is warranted to understand the demographic features of private patients. It was also interesting that IVF was a significant factor for the delivery period, as most of the procedures required for IVF occur before and during pregnancy (Medicare Australia, 2015). However, this finding showed that women who had undergone IVF treatment also incurred increased costs during the delivery period. This result could not be due to multiple births, as the data only included singleton deliveries.

The significance of the model of care factor suggested that for cases for which there was no private obstetrician, the cost was higher than if there was a private obstetrician. It is difficult to understand this result, prima facie, and further research is needed to understand it better. Note that this finding should not be confused with the effect the "Planning and Management of Pregnancy" fee that is paid to the obstetrician has on cost as there is a substantial Medicare rebate for this fee but this is covered under out-of-hospital costs. Therefore, this fee will be discussed in more depth in Chapter 5. Here the focus is on the hospital costs only.

There were a number of significant factors in the public models only – they included adverse births, private health insurance, smoking status, labour onset, diabetes and area of residence. Private health insurance was significant in the public model and showed that if the woman had private health insurance cover, the cost tended to

increase. This finding suggested that a woman who was a public patient with private health insurance would tend to incur more hospital costs than one without private health insurance. This could be an example of adverse selection of insurance, where those who are in poorer health (and therefore more costly) or older were more likely to take up private health cover; however, there would need to be more research done in this specific area to provide more evidence for this argument, especially given the government's policies designed to encourage young people (especially those aged under 30) to purchase private health insurance through punitive tax regimes for those who do not.

Whether labour was spontaneous or induced was another significant factor in the public delivery model. The coefficients for this factor suggested that spontaneous labour had slightly lower cost impacts compared to induction (which was the base level of the model) which makes sense because inductions usually involve more complex procedures and medications to help bring labour on in a woman who is not already in labour. The model also suggested that "No labour" had the lowest impact on overall cost and these cases all related to caesarean deliveries – this means these two factors should be considered together when assessing the cumulative impact on cost; that is, caesarean deliveries significantly increased costs but it was slightly offset by this factor (but the cumulative impact was that caesarean deliveries still increase costs).

The results for smoking status suggested that the more a woman smoked, the higher the impact on the cost. This finding made sense as there is already considerable literature on the adverse impact that smoking has on birth outcomes (Flenady et al., 2011; Hogberg & Cnattingius, 2007; Odendaal et al., 2008; Olsen et al., 1991;

Wisborg et al., 2001), and it is reasonable to see that this will have a flow-on cost impact, particularly as adverse births were also a significant cost risk factors themselves.

The diabetes factor that was significant in the public model relates to a pre-existing diabetes condition rather than gestational diabetes. The relationship between diabetes and poor health outcomes during pregnancy is well documented (Cheng et al., 2008; Flenady et al., 2011) so it is reasonable, again, to see that this factor will have a cost impact too.

Area of residence was largely differentiated by remoteness, and the coefficient suggested that more remote areas had lower costs than major cities. This was possibly an indication of the reduced access – and therefore lower services used – in remote areas. In addition to this, a study by Powers et al (2013) that considered birth intervention rates by area using ALSWH data concluded that care provided to labouring women may differ by area of residence. They explained that this difference may be due to both lack of choice of maternity services (such as availability of certain types of interventions) and differing expectations of women by area of residence leading to differences in birth interventions by metropolitan and non-metropolitan areas.

Finally, it was interesting to consider why these private health insurance, smoking status, diabetes, labour onset and area of residence were not significant in the private models, which generally resulted in fewer significant factors. Private patients represented approximately 40% of the total cost, and thus did not represent the majority of cost. Clearly, private health insurance status would not be relevant for private models, as the overwhelming majority of such patients would have private

health insurance but smoking status, diabetes, labour onset and area of residence were factors that could be applicable to private patients as well as public patients. One possible explanation for the absence of these factors was that the other significant factors in the private models (for example IVF) were swamping the effects of these factors. The more complex differences in the nature of these two types of patients that contributed to the drivers of these costs should be investigated in further research.

In terms of splitting the models into their frequency and severity components, it was not surprising that the antenatal and postnatal models were not conducive to this type of analysis, given the experience on sparse data in the total cost models. With regard to the delivery period, frequency models were not significant because typically women only need to visit the hospital once for the actual delivery of the baby during this time period. The severity models, however, provided more evidence about the robustness of the total cost models as they were very similar but with fewer significant factors. Mode of delivery was the main driver of the severity models for both public and private, with diabetes and age the other significant factors for each of these models, respectively.

Unfortunately, there were few direct comparisons that could be made with these results to previous research in the area due to the fundamental differences between this study and the previous studies both in terms of scope (see Section 2.2.6) and also in terms of data and methodology. It is also important to note the paucity of research in the area of maternal cost risk factors, making this study the first of its kind in Australia. Notwithstanding these differences, these results agreed with all the previous research in that the maternal hospital costs for women with adverse birth

outcomes were higher than those without adverse birth outcomes (Chollet et al., 1996; Gilbert et al., 2003; Gold et al., 2013; Luke et al., 1996; Mistry et al., 2013; Petrou & Khan, 2012; Ringborg et al., 2006). This thesis also showed that adverse births were statistically significant cost risk factors during the delivery period for public patients but were **not** statistically significant for private patients. This is an important finding from a policy perspective as it shows that the complexities of a mixed public-private health system (with tax regimes encouraging private health insurance to certain demographics) to be key drivers of the cost differentials seen, particularly in relation to adverse births. Note that this segmentation by public and private patients was not conducted in previous research in this area and results are also very specific to the Australian maternal health system. Furthermore, other factors (such as mode of delivery, IVF, area of residence and health related factors) were also identified here, an outcome that impacted on cost in a statistically significant way. The only paper that considered maternal cost risk factors in a similar way was by Gold et al. 2013, who found that caesarean deliveries have a significant impact on length of stay but not on cost. One of the reasons for this could be the way cost is defined through cost-charge ratios in the US and the exclusion of physician costs which would be included in the AR-DRG methodology used here. Gold et al. 2013 considered seven cost risk factors (see Section 2.2.1) and only found serious maternal complication to be of statistical significance. The current study considered a more diverse selection of cost risk factors through the ALSWH survey and was therefore able to link factors such as mental health and health behaviours to increased costs, offering insights that other studies have been unable to summon. These findings were important because they provided a comprehensive picture of what the most important drivers of the maternal hospital costs were. It also showed

the importance of considering hospital costs across all three sub-periods of the perinatal period and by public and private patients separately, as the results varied considerably between all of these segments, and the drivers of cost were different depending on the segment under consideration. The breadth of the factors studied and the modelling techniques ensured that only the most significant factors would be selected for further consideration from a public policy perspective.

4.5 Conclusion

Many maternal cost risk factors were identified for both public and private models across the three periods of care studied. There were many similarities between the relevant risk drivers of cost for private and public patients, such as mode of delivery and place of birth, but there were also a number of differences too, most notably the finding that the effect of adverse births was only significant for public patients but not private patients. Antenatal and postnatal models were relatively less important for cost considerations in comparison to the delivery models, as delivery represented the vast majority – around 80% – of the total cost.

Given the focus of this thesis is on public costs, the maternal cost risk factors from this model should be considered in more detail from a public policy standpoint. There were numerous further research points identified that need exploration before public policy recommendations can be put forth in some areas; these included mode of delivery (particularly understanding drivers of increased caesarean delivery), the complexities of care for IVF patients, pathways or model of care and in particular the interactions between specialist and GP care and the drivers of the take up of private health insurance. These issues are discussed in more detail in Chapter 6. In addition to this, smoking status will also be considered further in Chapter 6 from a health

policy perspective. This factor was selected because it is a well-known modifiable risk factor of poor maternal health and birth outcomes and there is already a depth of relevant research and information available that can be used as further evidence to inform policy.

5

6 Results Part 2 – Out-of-hospital costing

6.1 Introduction

Out-of-hospital costs represented approximately 7% of expenditure in maternity services in Australia in 2008 (Bryant, 2008). The main services that gave rise to the expenditure in this area were doctor and specialist services during the antenatal care of a woman. The aim of this chapter is to identify and understand factors related to increased maternal out-of-hospital costs that can then be used to develop policy to ensure cost effectiveness in this area.

6.2 Methods

6.2.1 Summary of data

The datasets used for this study were obtained through the linkage of Medicare Benefits Schedule (MBS) data and ALSWH data. Table 5.1 summarises which years were available for the datasets used in this study. The timeframe was constrained by the MBS data as it was used for the cost data and cuts off two years prior to the ALSWH data. There were 2520 women in the final complete dataset used for modelling with 4546 babies (over the years 2000-2010). Section 5.2.2 discusses how the cost variable was calculated using the MBS dataset.

Table 5.1: Out-of-hospital datasets

Dataset	**Years**
ALSWH	2000-2012
Medicare Benefits Schedule	1997-2010

Table 5.2 gives summary statistics of some key variables in the final linked dataset:

Table 5.2: Out-of-hospital data statistics

Factor	% babies	% cost
IVF		
No	53%	60%
Yes	2%	7%
Missing	44%	33%
Area		
Major cities of Australia	50%	59%
Inner regional Australia	28%	24%
Outer regional Australia	17%	13%
Remote Australia	4%	3%
Very remote Australia	1%	0%
Overseas participants	1%	0%
Missing	1%	1%
Smoking status		
Never smoker	65%	67%
Ex-smoker	23%	24%
Smoker, less than 10 per day	5%	4%
Smoker, 10-19 per day	4%	3%
Smoker, 20 or more per day	2%	1%
Missing	0%	0%
Stress about own health		
N/A	0%	0%
Not at all stressed	38%	33%
Somewhat stressed	42%	43%
Moderately stressed	14%	16%
Very stressed	4%	5%
Extremely stressed	1%	2%
Missing	0%	0%
Diagnosed or treated with anxiety		
No	90%	89%
Yes	4%	5%
Missing	7%	6%

Factor	% babies	% cost
Episodes of intense anxiety		
No	53%	60%
Yes	2%	7%
Missing	44%	33%
Diagnosed or treated with postnatal depression		
No	91%	90%
Yes	9%	10%
Missing	1%	0%
Specialist use		
No	39%	27%
Yes	60%	72%
Missing	1%	0%
GP use		
None	7%	5%
1-2 times	33%	32%
3-4 times	27%	29%
5-6 times	13%	15%
7-9 times	7%	8%
10-12 times	5%	5%
More than 12 times	6%	5%
Missing	2%	1%
Private health		
No	44%	25%
Yes	56%	75%
Maternal diabetes		
No	95%	95%
Yes	1%	1%
Missing	4%	4%
Adverse births		
No	89%	88%
Yes	8%	10%
Missing	2%	2%

6.2.2 Cost definition: Inflated benefit

The definition of cost in this chapter varies from that used in the preceding hospital costing chapter as the MBS data contains information on the actual payment amount from the government for the service. The variable used in the data was labelled "benefit" and refers to the amount the government reimbursed the patient, taking into account whether the patient was private or public and whether they had reached the

safety net or not. Benefit does not include co-payments, and thus all the analyses should be interpreted as the cost to the government.

As benefit was in historical monetary unit values in the data, it was inflated to 31st December 2015 using the inflation rates for Medicare Services, available in the AIHW Health Expenditure reports (Australian Institute of Health and Welfare, 2014b). The data were available until 2012 so a projection was required for inflation rates in 2013-2015. The inflation for these years was estimated at 2.3% by considering the recent inflation rates for Medicare Services and the selected rate represents the 2012 rate and also a five-year average rate. Forward projections of Health inflation from the ABS (Australian Bureau of Statistics, 2014) was also considered and the selected rate represents a figure consistent with overall Health inflation expected in 2013-2015.

Therefore, year on year inflation was determined as shown in Table 5.3.

Table 5.3: Inflation Index for MBS benefit

Year	Inflation Index
1997	1.017
1998	1.027
1999	1.028
2000	1.044
2001	1.058
2002	1.054
2003	1.053
2004	1.078
2005	1.056
2006	1.031
2007	1.027
2008	1.039
2009	1.020
2010	1.015
2011	1.017
2012	1.023
2013	1.023
2014	1.023
2015	1.023
2016	1.023

6.2.3 Adverse birth definition

The definition of adverse birth in this chapter varied from that used in the preceding hospital costing chapter because there were no data available to assess congenital conditions and neonatal deaths. Therefore, only premature, low birth weight and stillbirths were included in the definition of adverse births. Further, it is important to note that these items were used from the ALSWH survey, so were self-reported, a feature that differs from the hospital costing study where the items were obtained from administrative datasets. However, validation of the self-report measure of adverse births in ALSWH has been conducted and found to be reliable (Gresham et al., 2015).

Note that direct comparisons cannot be made between this study and the hospital study as the datasets used were different. There were different samples of ALSWH

participants used in each study and different definitions of each of adverse births and costs.

6.3 Results

The modelling was split into three phases: exploratory analysis, classification and regression trees (CART) and generalised linear models (GLMs), and the results of each are discussed in turn.

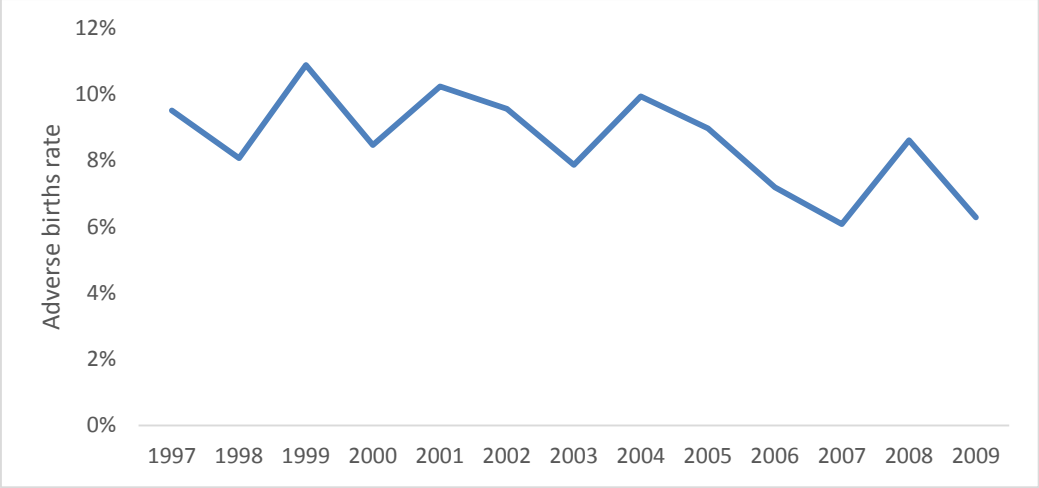
6.3.1 Exploratory analysis

The aim of the exploratory analysis was to better understand the data and explore specific areas of the data that will impact on key modelling decisions in more detail. Most of this initial process was conducted considering variables one at a time, so complex interrelationships among multiple variables were not identified. The CART and GLM procedures fit later, address more complex multivariate structure in the data.

6.3.1.1 Rates of adverse births

The definition for adverse births was taken from the ALSWH survey, so it was based on maternal self-reports for premature births, low-birth weight and stillbirths. It has been found that a high confidence can be placed on self-reported perinatal outcomes from this survey when compared to administrative data such as the PDC (Gresham et al., 2015). Figure 5.1 shows the adverse birth rate by year.

Figure 5.1: Adverse birth rate by year



From Figure 5.1, the rate of adverse births has been fairly volatile through time because of the low-prevalence nature of the condition; however, a decreasing trend was nevertheless evident. This outcome was somewhat unexpected, as it differed in direction from the trend seen in the hospital costing, which was driven by the higher proportion of caesarean deliveries in later years compared to earlier years (delivery costs also made up the majority of the hospital costs so this was a key driver). However, in this case, the majority of the cost accrued in the antenatal period, and the drivers were more difficult to understand without consideration of how other variables varied. Nonetheless, a particular feature of the data with regard to the ageing cohort of women in ALSWH was investigated further to provide some insight into this trend.

The ageing cohort of women in the ALSWH survey occurs because the same cohort of women was surveyed every 3-4 years. Thus, the median of the age distribution by year will grow each year. The following graphs depict the adverse births rate by two age groups.

Figure 5.2: Adverse birth rate by age

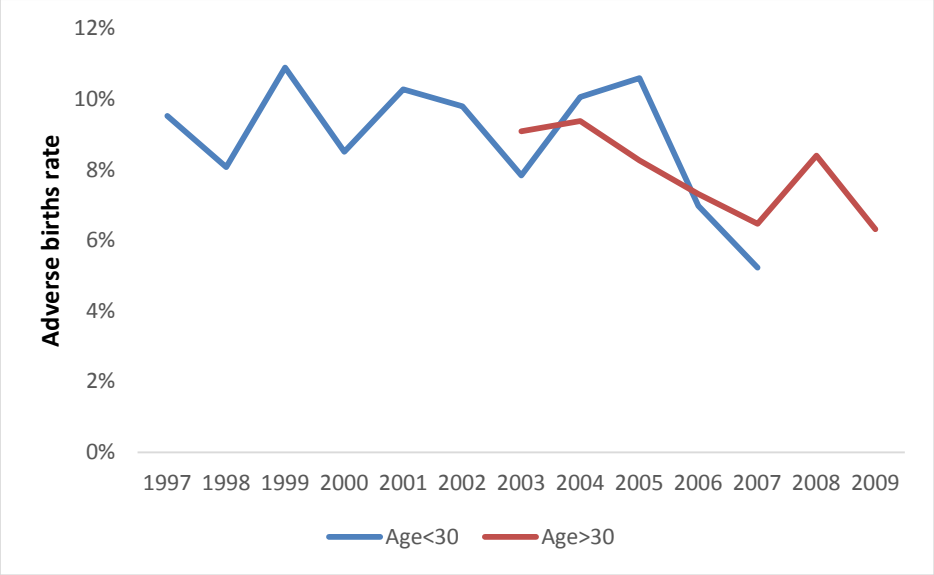
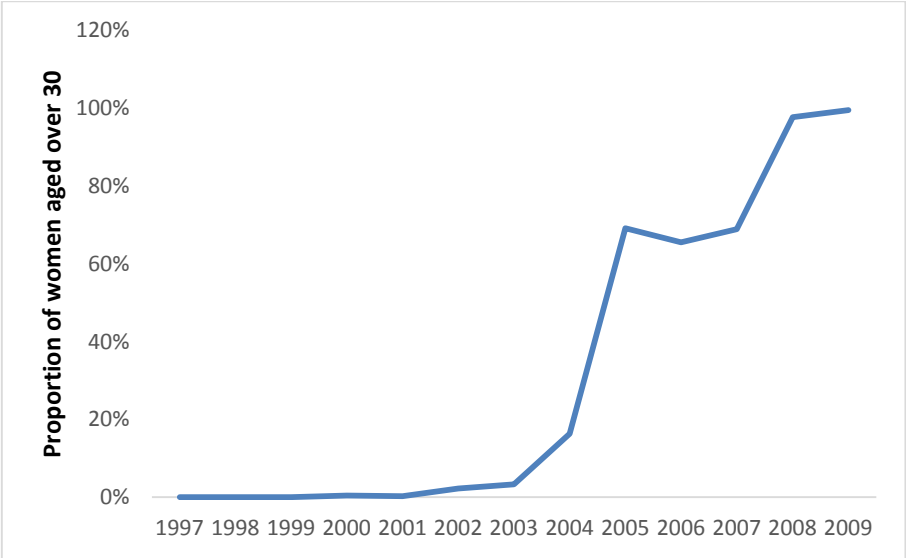

12%
10%
8%
6%
4%
2%
0%
Adverse births rate
1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009
Age<30
Age>30

Figure 5.3: Proportion of mothers aged over 30 by year



The interesting feature was that mothers aged over 30 have a relatively lower adverse birth rate than younger mothers, as evident in the years 2004-2006, when there was a material proportion of both age groups present in the data. As these mothers represented a much higher proportion of the sample in later years, the overall adverse birth rates was dominated by these mothers, and therefore lower than in earlier years for which these mothers represented a lower proportion of the total sample. The reasons why these mothers experienced lower adverse birth rates is difficult to assess considering age alone, as age may be correlated with other factors that are not taken into account within this one-way view of the data, but this analysis showed that age should be a factor considered in the multivariate modelling. The multivariate modelling provides more insight into the true impacts of multiple risk factors on cost, taking into account the correlations between covariates and the complex multivariate nature of the data. In addition to this, age-based effects need to be considered carefully due to the cohort-based nature of the ALSWH data, and the

multivariate modelling will provide a better framework to assess this more accurately.

6.3.1.2 Costs of adverse births

Table 5.4 summarises the data by adverse births and related out-of-hospital costs for both small and large cost items. The definitions of large items are in Table 5.6.

Table 5.4: Summary of maternal out-of-hospital costs by adverse births

TOTAL COSTS					
Adverse birth	**Antenatal**	**Delivery**	**Postnatal**	**Total**	**No. of babies**
No	6,269,486	676,624	2,928,661	9,874,770	4,061
Yes	697,706	87,161	384,292	1,169,159	378
Missing	148,970	14,873	76,062	239,905	107
Total	7,116,162	778,658	3,389,015	11,283,835	4,546
% of total cost	63%	7%	30%	100%	
SMALL COSTS					
Adverse birth	**Antenatal**	**Delivery**	**Postnatal**	**Total**	**No. of babies**
No	3,798,508	166,799	2,164,966	6,130,273	4,061
Yes	449,810	33,736	274,067	757,612	378
Missing	102,585	3,701	56,794	163,079	107
Total	4,350,902	204,236	2,495,826	7,050,964	4,546
% of total cost	62%	3%	35%	100%	
LARGE COSTS					
Adverse birth	**Antenatal**	**Delivery**	**Postnatal**	**Total**	**No. of babies**
No	2,470,978	509,825	763,695	3,744,498	4,061
Yes	247,896	53,425	110,225	411,547	378
Missing	46,385	11,172	19,269	76,826	107
Total	2,765,260	574,422	893,189	4,232,870	4,546
% of total cost	65%	14%	21%	100%	

Table 5.5: Summary of average maternal out-of-hospital costs by adverse births (Ab)

TOTAL AVERAGE COSTS				
Adverse birth	**Antenatal**	**Delivery**	**Postnatal**	**Total**
No	1,544	167	721	2,432
Yes	1,846	231	1,017	3,093
Missing	1,392	139	711	2,242
Total	1,565	171	745	2,482
Ab: non Ab	1.20	1.38	1.41	1.27
SMALL AVERAGE COSTS				
Adverse birth	**Antenatal**	**Delivery**	**Postnatal**	**Total**
No	935	41	533	1,510
Yes	1,190	89	725	2,004
Missing	959	35	531	1,524
Total	957	45	549	1,551
Ab: non Ab	1.27	2.17	1.36	1.33
LARGE AVERAGE COSTS				
Adverse birth	**Antenatal**	**Delivery**	**Postnatal**	**Total**
No	608	126	188	922
Yes	656	141	292	1,089
Missing	434	104	180	718
Total	608	126	196	931
Ab: non Ab	1.08	1.13	1.55	1.18

These tables show that overall average maternal out-of-hospital costs, when there was an adverse birth, was 27% higher than the average maternal out-of-hospital costs when there was no adverse birth. The cost differences were highest in the delivery and postnatal periods, however over 60% of the total cost was in the antenatal period. This finding contrasts with hospital costs where the majority of the cost was in the delivery period and the cost differentials were greatest in the delivery and antenatal periods. Table 5.4 also shows that the overall rate of adverse births for these data was 8%. Small costs represented 63% of the total and the relative proportions of costs across the three periods were similar to those found for the total costs. For large costs however, there was a greater proportion in the delivery period, which was offset by a lower proportion in the postnatal period. This was because

many of the large costs were incurred during delivery (for example, the obstetrician fee must be paid during this time). The cost differentials also varied considerably between the small and large costs cases, with the small costs showing higher cost differentials in the antenatal and delivery periods, while the large costs had higher cost differentials in the postnatal period. The reasons for these cost differentials will be better understood when they are studied within the multivariate framework.

The costs were also summarised by year in Figure 5.4.

Figure 5.4: Out-of-hospital costs per baby per year

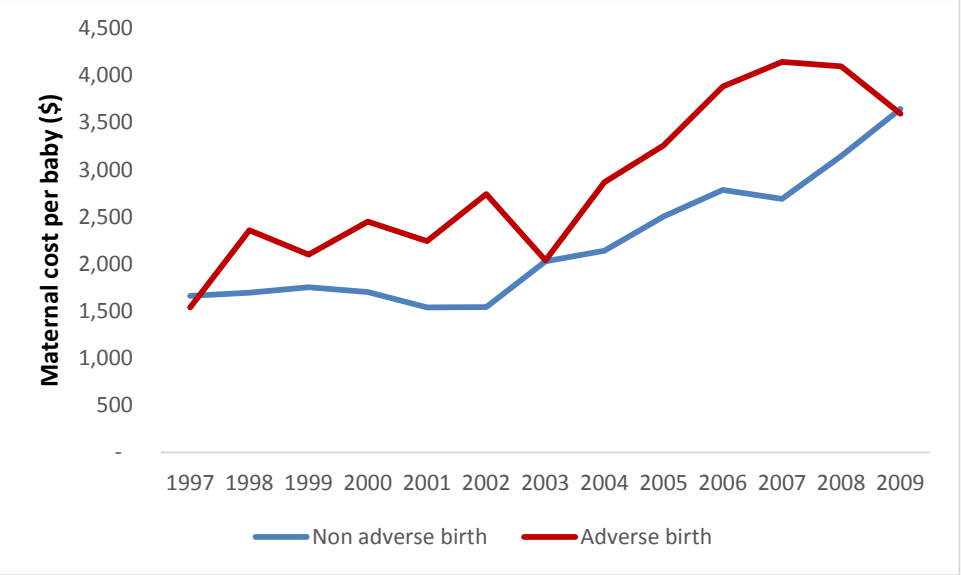


Figure 5.4 clearly shows an increasing trend in the cost over time for non-adverse births; similarly, the trend in adverse births also appeared to be increasing; although, given the relatively low numbers of adverse births, the cost data for this category was slightly more volatile (especially in earlier years). The costs of adverse births were also higher than non-adverse births across all years except 1997 and 2009, for which they were very similar. The most interesting finding in this trend analysis was, however, the rising cost increases since 2002. Note that these costs already take into

account inflationary increases so there must be other reasons for the notable year on year increases since 2002 and this phenomenon warrants further investigation.

Further investigation into these increases revealed two key reasons for the cost rises. The first is that there was a greater use of services overall; that is, the number of items claimed per baby was also increasing over time (see Figure 5.5 below), and the year it started increasing significantly was also 2002. This phenomenon could be understood in a number of ways – for instance, mothers could be using more services, or the government could be making more services available to claim through Medicare (that previously were not covered under Medicare, so they would be, in effect, broadening Medicare coverage). A further contributing factor to this finding was the noticeable increase in the percentage of babies that had mothers with private health insurance (see Figure 5.6 below). Given the greater proportion of women with private health cover, there was likely to be more claims through Medicare for services they tended to use (such as specialist services during pregnancy). So while it appeared as though Medicare costs to the government were increasing, these could be offset by lower hospital costs because the higher proportion of women with private health cover means they were likely to be using private hospitals for hospital related services (such as delivering their babies). Note that making more services claimable through Medicare also does not necessarily mean the government is paying more overall, as these services may have previously been funded from elsewhere (for example, through hospitals) and this cost may have been simply transferred to Medicare, at no net change to government expenditure.

Figure 5.5: Number of items claimed per baby (1997-2009)

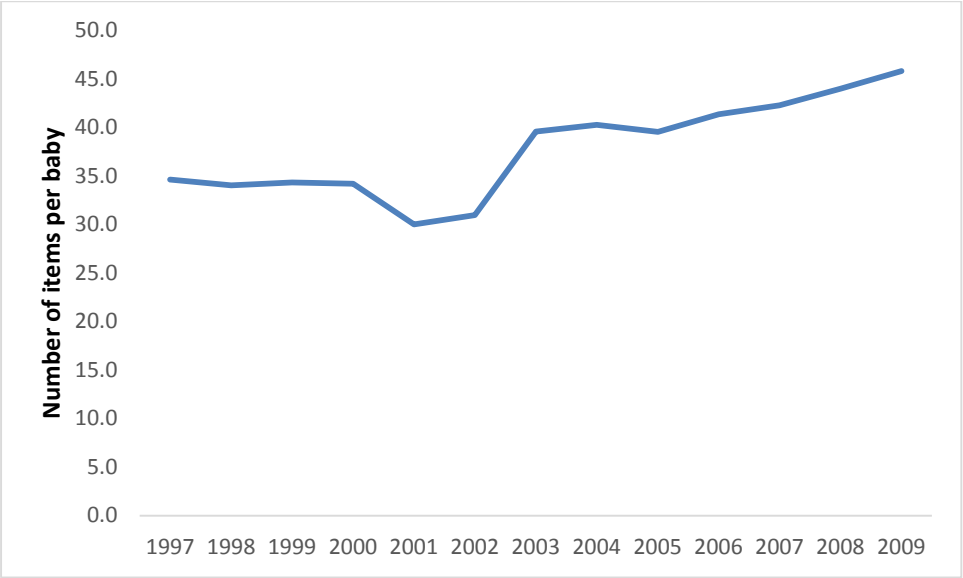
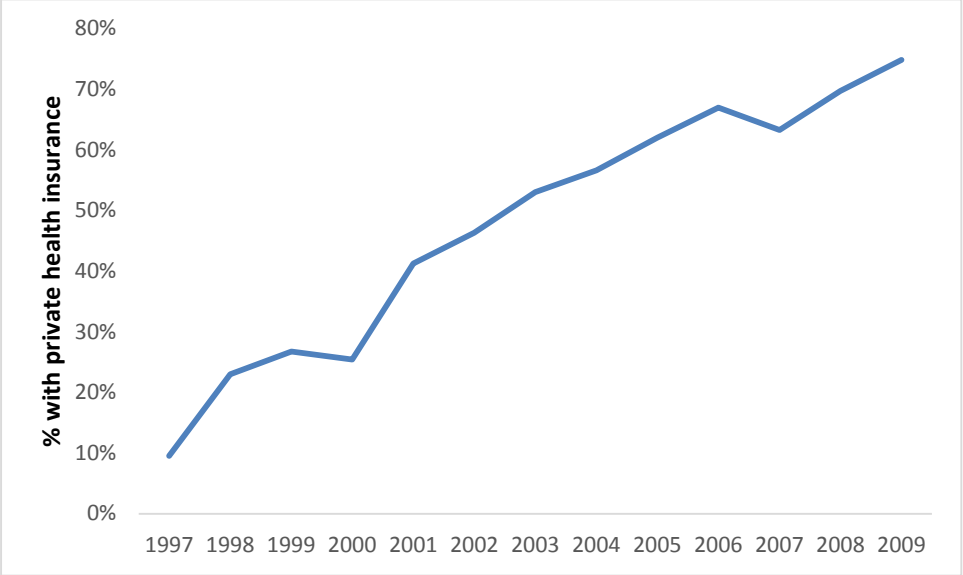


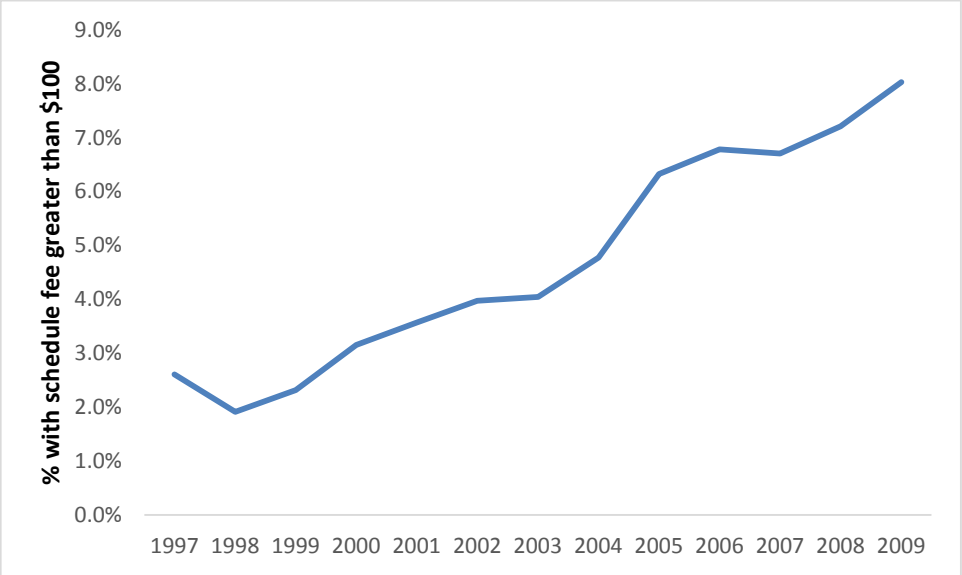
Figure 5.6: Proportion of babies with private health insurance



The second plausible reason for the increase in costs was the "mix" of service use changing over time. Figure 5.7 shows "High cost" services (that is, those with a scheduled fee exceeding $100) represented a higher proportion of total services used in later years compared to earlier years. This resulted in overall cost increases by

year because women were using more expensive services in later years. This may reflect their choice and they may be actively substituting lower cost services for higher cost services – an obvious example of this during antenatal care would be switching from GP services to specialist services. Unfortunately, data were not available to test this theory, because Medicare does not collect information on type of GP service, so it was not possible to determine whether a given GP consultation was for an antenatal visit or something else. However, the other evidence (change in mix of service and increase in proportion of those with private health insurance) suggested this was a plausible explanation.

Figure 5.7: Change in mix of services (1997-2009)



Given some of the observations above, it was important to also consider changes in the environment and the structure of the Medicare system over time, as these issues had the potential to impact the analysis. The Strengthening Medicare package introduced in 2004 included a number of changes that impacted the area of perinatal health care, including changes in bulk billing, and the introduction of the EMSN and Item 16590 (for Planning and Management of Pregnancy) in 2004 (Centre for Health

Economics Research and Evaluation, 2011). Furthermore, a previous CHERE report in 2009 showed some of the major impacts of the introduction of EMSN in 2004 were in the areas of obstetrics, ART and pregnancy scans (Centre for Health Economics Research and Evaluation, 2009). The former report looks at the impact of the rebate caps that were introduced in January 2010 to target these areas. The immediate implication of these policy changes was firstly an increase in rebates provided through EMSN since 2004 (due to the introduction of new obstetric related items into Medicare). However, these rebates have started to reduce with the introduction of the caps. As the data available for this thesis ends at the end of 2009, the impact of the caps introduced in January 2010 cannot be considered here. The other major impact of the EMSN was a transfer of services from in hospital to out-of-hospital (Centre for Health Economics Research and Evaluation, 2009).

These data showed that while there was a definite increase in costs starting around 2002 (that is, before the introduction of EMSN) and costs increased steadily from then to the end of the dataset period in 2009, the introduction of EMSN in 2004 does not show a noticeable additional change in the trend that was already apparent from 2002. Given this, it is likely that the two reasons given for the increases above (increase in the use of Medicare services and change in the mix of services) were the overriding factors in the steady increase in costs. Furthermore, the items associated with most of the changes described above have been removed and will be analysed separately when large costs are considered. As the aim of the analysis is to identify the risk factors driving cost, all of the data will be used for the modeling, and year will be considered as a cost risk factor (although time is clearly not causally related to cost and is included only as a structural model component) to understand whether any of these issues related to historic changes in Medicare have a significant impact

on cost when considered with other cost risk factors. Note that the multivariate approach adopted in this thesis is ideal to understand the suspected reasons for increasing costs as these models consider each factor in isolation but also in the presence of all other factors.

6.3.1.3 Cost distributions

The next step as a precursor to modelling was to characterise the cost distributions. The cost distribution for the complete data appeared skewed strongly to the right as shown in Figure 5.8:

Figure 5.8: Total maternal out-of-hospital cost distributions (untransformed)

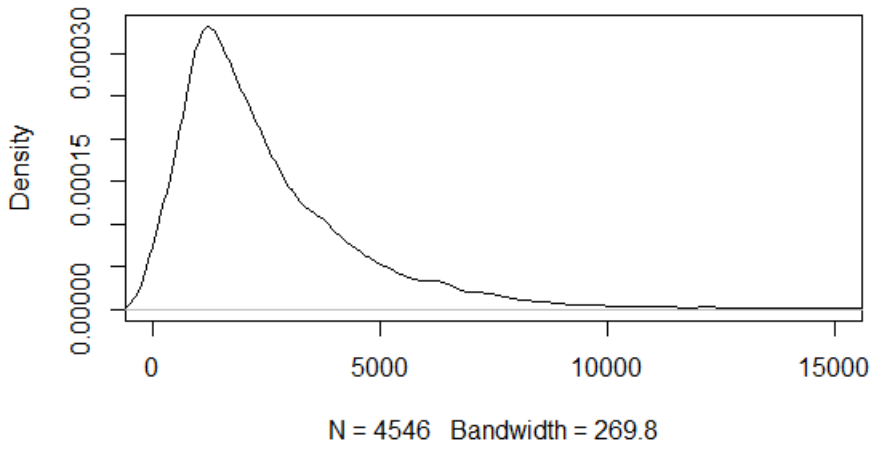
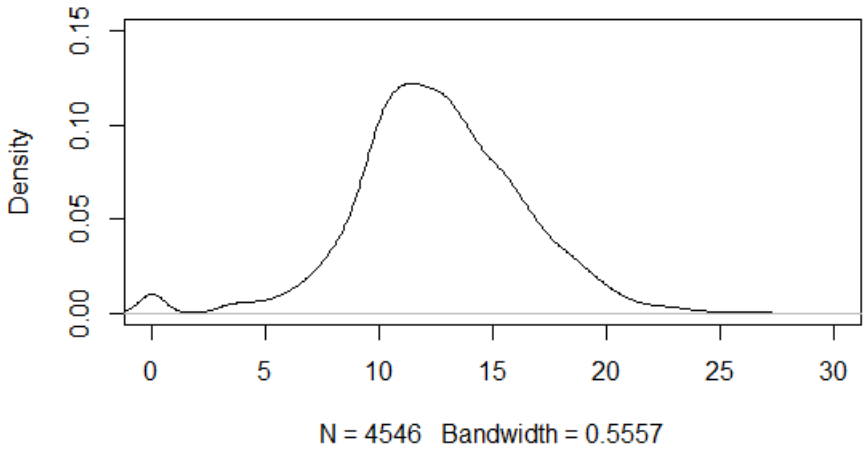
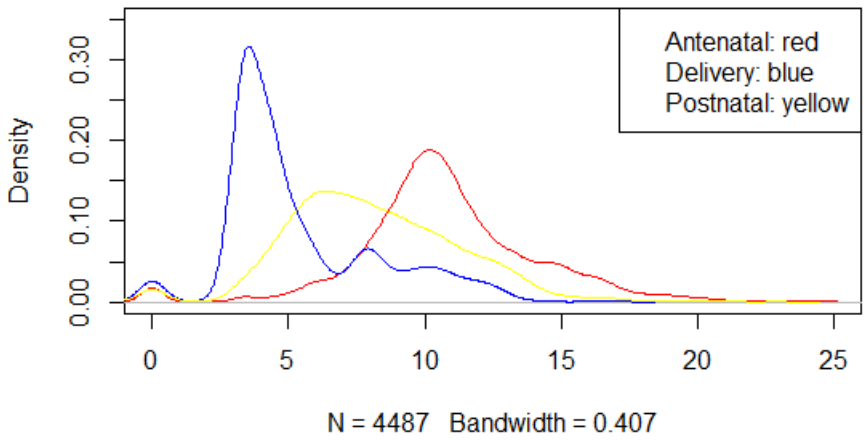


Figure 5.9: Total maternal out-of-hospital cost distribution (transformed)



However, when the total cost was transformed to an approximately symmetric distribution, a small secondary mode at zero became visible. The two main modes visible in the transformed density depicted in Figure 5.9 relate to zero cases (that is, cases where women did not claim any MBS benefits), a condition that represented around 1% of the records, and non-zero cases (that is, cases where women did claim MBS benefits). There were no outliers removed from the analysis. The distributions varied by period and are shown in Figure 5.10.

Figure 5.10: Maternal out-of-hospital cost distribution by period (transformed)



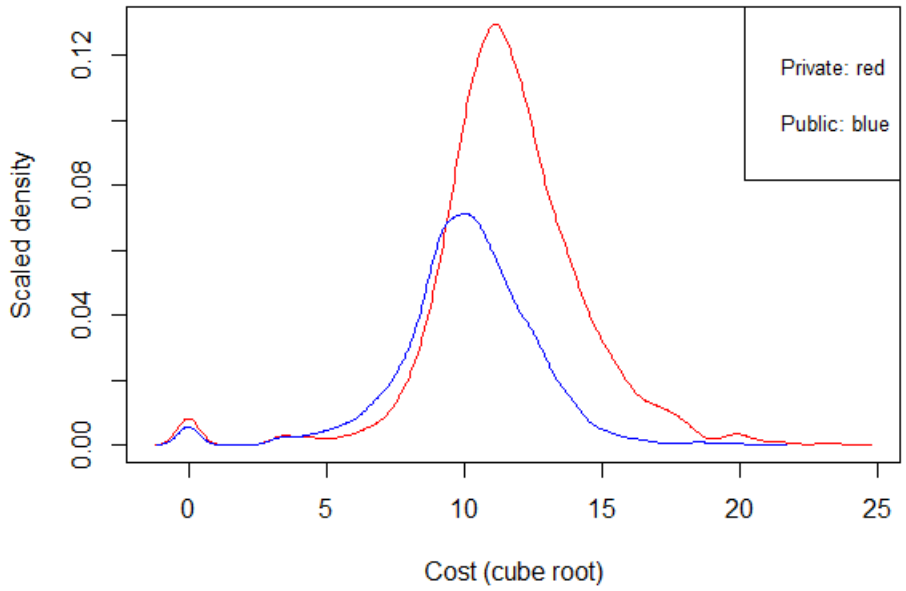
The distribution of cost by period was characterised by two main modes but there was evidence of a third mode for the delivery period. The additional mode was largely due to differences in the structure of the public and private health care systems, and this explanation was discovered by investigating the types of items claimed by the women within this additional mode and whether they had private health insurance. These items that women used related primarily to obstetric care provided by a specialist obstetrician (for example, items 16519, 16522 and 16590). Given that these women were using specialist items, it was observed as more likely that they had private health insurance and had chosen the private pathway for antenatal care and delivery. This meant they would see a private obstetrician for their antenatal care, and then this obstetrician would deliver the baby in a private hospital. Note that it was possible for women without private health insurance to see a private obstetrician (and, in fact, there were no rebates available from private health insurance in Australia for these specialist visits during this time so these women would pay the same amount out-of-pocket as one with private health insurance); however, as these women were more likely to deliver in a public hospital they were also more likely to access antenatal care through the public hospital or their GP.

Given these findings, the data were then split by "public" and "private" using the question from the ALSWH survey about whether the woman had private health insurance for hospital cover or not. In cases for which the response was "Yes", these women were categorised as "private" and all other women were categorised as "public". Note that there must be some caution taken in using this definition, as a woman falling in the "private" group does not guarantee that she was a private patient for all Medicare services; rather, it simply means the woman had a greater chance of accessing private services (as they could always opt to be treated as a

public patient). Similarly, a patient in the "public" group could also be using private services, but given they did not have private health cover, it was reasonable to suggest these women were more likely to be accessing public services. There was also an issue with women who had private health cover in-between surveys, and accessed private services in this time, but their survey responses were "No" to the private health insurance question at the times the surveys were taken. However, this was considered to be a relatively minor issue, as it was unlikely there would be many occurrences of women who have held this sort of cover only in-between surveys. This circumstance highlights the problems that arise with trying to accurately assess whether a patient is public or private in data such as this because patients can so easily transfer from one status to the other, regardless of whether they have private health cover or not. Notwithstanding this, it was thought reasonable to analyse the data using the question regarding private health insurance cover as the determinant of private/public status as this was a primary indicator of whether a woman was more likely to have accessed private services. Note that this definition of private and public varies from that used in hospital costing case, because patient status *was* available in the APDC dataset, and this recorded status gives a more accurate indication of whether the patient was treated as a public or private patient. Unfortunately, data for this variable were not available here.

The following figure shows the distribution of costs by public and private patients. Here raw cost was transformed by a cube-root transformation so that the distributions observed were closer to symmetric. Note that these cost distributions were scaled by the weight that they represented of the total distribution (private is approximately 65% and public is 35%).

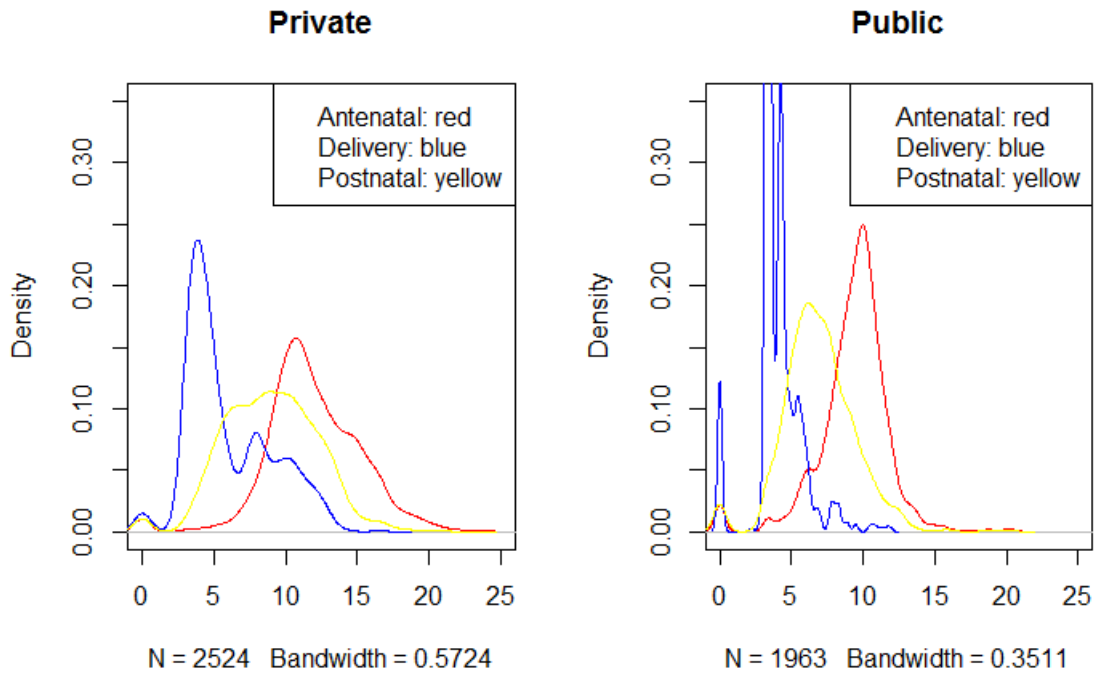
Figure 5.11: Public vs private maternal out-of-hospital cost distribution



Clearly there was a qualitative difference in the distributions of (transformed) cost between public and private patients, this difference most evident in the right tail – transformed private costs had a longer tail, arising from more frequent occurrences of larger costs. This phenomenon occurs because private services tend to be higher cost; for example, an antenatal service through an obstetrician will cost substantially more than antenatal service through a GP, and correspondingly the benefit paid will also be higher for these specialist services. Therefore, observing a greater portion of cost from the private sector was very much in line with expectations. Given these structural differences yielding differences in (transformed) cost distributions, it made sense to divide the analysis into private and public cases, as it was thought likely that the cost drivers would be quite different between the two settings.

Next, cost distributions for the three cost periods were compared for private and public cases separately.

Figure 5.12: Public vs private maternal out-of-hospital cost distribution by period



The tri-modal distributions remain for (transformed) private costs, with two small modes and one primary mode for antenatal and postnatal and, significantly, three clearly separated modes for delivery. The situation is similar for (transformed) public delivery costs; however, data in this period was very sparse, leading to high variability in the estimated cost distribution, particularly in the delivery period. This variability was driven by large cost items, which are discussed below (much of the variability was removed when the cost distribution was split into small and large).

The modes in the private data were investigated in more detail by considering the records that contributed to each respective mode. For private delivery and postnatal cases, the third mode was due mainly to item 16519, which relates to the management of labour and delivery of the baby (including caesarean delivery). It appears some of the delivery costs have been allocated to the postnatal period (for

instance, they may have only been paid after delivery). The third mode for the private antenatal period arises mainly from item 16590, which relates to the large Planning and Management for Pregnancy fee for antenatal care. Finally, the additional modes in the public model pertain mainly to item 16500 (which relates to an antenatal attendance). As the trend identified in this analysis showed that it was the large specialist (particularly obstetric) items that explain these modes, a more detailed item analysis was undertaken, and a number of other items were identified as high cost. These items were grouped to identify "large" costs, and are shown in Table 5.6. Note that the IVF items included in this group were discovered after the initial modelling stage as they were swamping the effects of other variables in the GLM fits. An investigation of only IVF patients was undertaken in order to decide how best to handle this issue. First, it was discovered that two items (13200 and 13201) had extremely high average costs and were causing other factors to be swamped. The other IVF-related items had a much lower average cost and were not dominating other factors. Therefore, it was decided that these two large IVF items would be placed with other large items and analysed separately through the large item analysis. As an alternative, all IVF items could have been removed from this analysis and modeled separately, however, there was not enough volume in this group to produce reliable model fits. Furthermore, the impact of IVF (without the extremely high cost items) is an interesting effect in its own right.

This investigation about IVF also revealed that patients using IVF services tended to be high service use patients so, not only were they accessing high cost IVF services, they were also accessing other services such as specialists, GPs and scans more than other patients, further driving up their individual costs. Note that while IVF-related items had extremely high average costs they were not the core underlying reasons for

the multiple modes in the overall cost distributions (as outlined above) as they represented very low frequency events. However, they were grouped with large costs for a different reason, namely, to avoid swamping the effects of other factors on small costs within the modelling exercise.

Following these investigations, the final group of large items identified comprised: 16519, 16590, 16522, 16520, 16500, 20850, 18216, 18226, 13200 and 13201. The following table describes what services these items relate to.

Table 5.6: Large cost item numbers and type of service

Item Number	**Type of service**
16519	Management of labour and delivery
16590	Planning and management of pregnancy fee
16522	Complicated delivery
16520	caesarean delivery
16500	Antenatal attendance
20850, 18216 & 18226	Anesthesia
13200 & 13201	IVF

Once large items were removed, the resultant distributions for (transformed) small and large costs were as follows in Figure 5.13 and Figure 5.14 respectively.

Figure 5.13: Maternal out-of-hospital costs (small) distribution by period

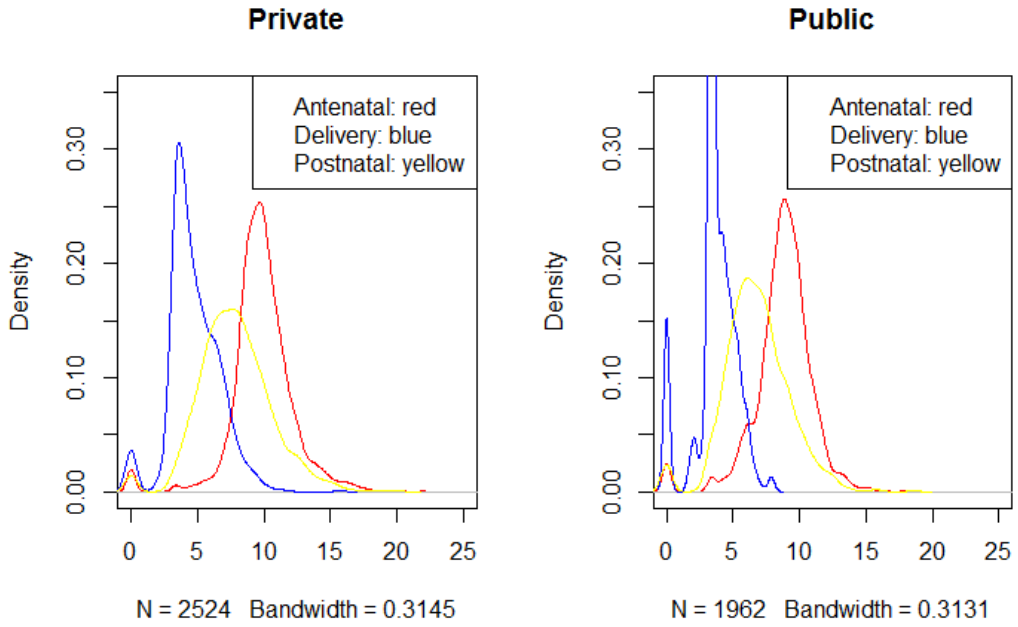
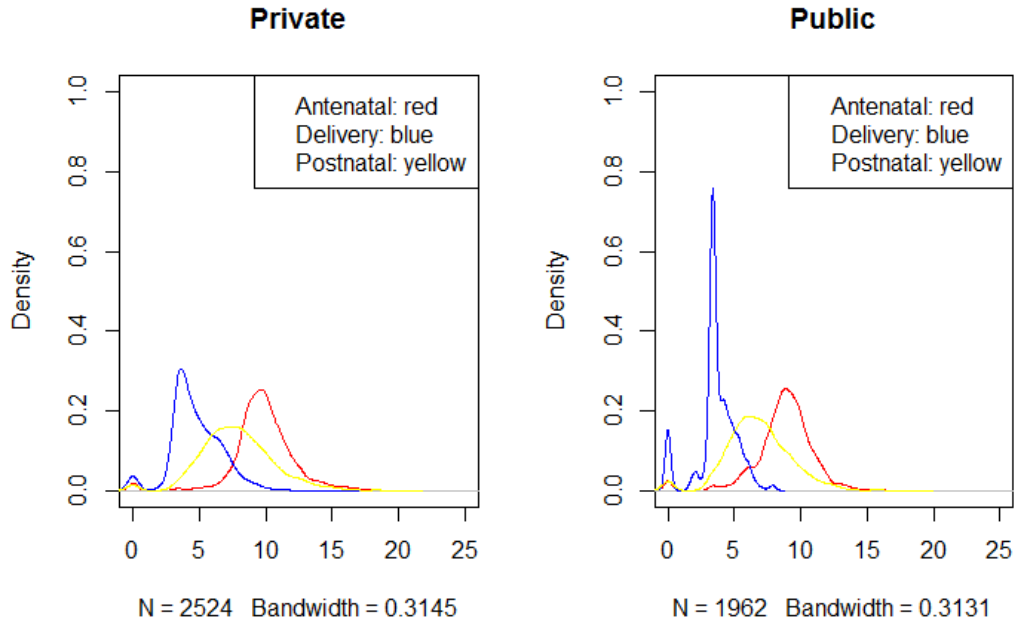


Figure 5.14: Maternal out-of-hospital cost (large) distribution by period



Most of the issues with multiple modes have largely vanished through the allocations to small and large cost groups and the resultant distributions are closer to the kinds of unimodal distributions better handled within conventional modelling approaches.

6.3.2 Classification and Regression Trees

Given the results of the exploratory analysis, in particular the issues identified with large cost items and the observed distributions for public and private costs, data were considered separately for small, large, public and private cases. All the years available in the dataset have been used for both the CART and GLM modelling exercises. Regression tree models were fit relating costs during each period to all covariates available. A complete list of possible covariates is in Appendix A and key factors were discussed in Section 3.4.3 under the broad categories of health service use, obstetric factors, reproductive factors, demographic factors, health behaviours and psychological and physical health factors. For reference purposes, the complete variables selected from the CART analysis is shown in Appendix F but simplified versions of the trees are shown graphically here, and Table 5.7 below provides more information on the most important selected factors shown in these trees (including a description of the label as some have been abbreviated to fit in the diagrams).

Table 5.7: Out-of-hospital costing – key CART factors

Tree label	Description	Label
Infertil	Have you and your partner (current or previous) ever had problems with infertility (that is, tried unsuccessfully to get pregnant for 12 months or more)?	1= Never tried to get pregnant 2= No problem with infertility 3= Yes, but have not sought help/treatment

		4= Yes, and have sought help/treatment"
Speciali	Have you consulted a specialist for your own health in the last 12 months?	1= Yes 0= No
Hgt	Height of mother	Continuous
Intanx2	In the last 12 months, have you had any of the following: Episodes of intense anxiety (eg panic attacks)	1= Never (No) 2= Rarely 3= Sometimes 4= Often
Cancer5	Have you ever been told by a doctor that you have: Cancer	1= Yes 0= No
Ivf	Do any of the following apply to you? I am using/have used In Vitro Fertilisation (IVF)	1= Yes 2= No
Seifaadv	Socio-economic index for areas (SEIFA) Index Socio-economic Advantage/Disadvantage	Continuous (higher score indicates more advantage)
Mostang	Mean value of “MOS” scale values for Tangible Support, 1 to 5	1 to 5 Higher scores for subscales and the index indicate more social support.
ferthorm	I am using/have used fertility hormones (eg Clomid)	1= Yes 2= No
Bmi	Body Mass Index	Continuous
Consultg	Frequency of GP consultations	0= None 1= 1-2 times 2= 3-4 times 3= 5-6 times 4= 7-9 times 5= 10-12 times 6= More than 12 times

ariapgp	Accessibility/Remoteness Index of Australia (ARIA+) grouped	1= Major cities of Australia 2= Inner regional Australia 3= Outer regional Australia 4= Remote Australia 5= Very remote Australia 6= Overseas participants
accessgp	Access to a GP who bulk bills	1= Excellent 2= Very good 3= Good 4= Fair 5= Poor 6= Don't Know
consulth	Have you consulted the following people for your own health in the last 12 months? A hospital doctor (eg. in outpatients or casualty)	1= Yes 2= No
breastfe	Months of breastfeeding	Discrete for months
Seifadis	Socio-economic index for areas (SEIFA) Index Socio-economic - Disadvantage	Continuous (higher score indicates more advantage)
Emergenc	Emergency caesarean	1= Yes 0= No
Hrswork	Hours worked	1= 1-15 hrs 2= 16-24 hrs 3= 25-34 hrs 4= 35-40 hrs 5= 41-48 hrs 6= 49+ hrs 7= not in labour force / unemployed
oftensmo	How often do you currently smoke cigarettes or any tobacco products?	1= Daily 2= At least weekly (but not

		daily) 3= Less often than weekly 4= Not at all
metsmins	Exercise score	Continuous (higher score indicates more exercise)
Postnata and pnd2	Postnatal depression	1= Yes 0= No
mosaff	Mean value of MOS scale values for Affectionate Support, 1 to 5	1 to 5 Higher scores for subscales and the index indicate more social support.
Age	Maternal age	Years
ownhealt	Over the last 12 months, how stressed have you felt about the following areas of your life: Own health	1= Not applicable 2= Not at all stressed 3= Somewhat stressed 4= Moderately stressed 5= Very stressed 6= Extremely stressed
Anxiety	In the past three years, have you been diagnosed with or treated for: Anxiety/nervous disorder	1= Yes 0= No (from coding)
Stress	Mean stress score	0,1,2,3,4 (Higher value means more stress)
Income2	What is the average gross (before tax) income that you receive each week, including pensions, allowances and financial support from parents?	1= No Income 2= $1 - $119 ($1-$6.239 annually) 3= $120 - $299 per week ($6,420 - $15,999 annually) 4= $300 - $499 per week ($16,000 - $25,999 annually) 5= $500 - $699 per week ($26,000 - $36,999 annually) 6= $700 - $999 per week

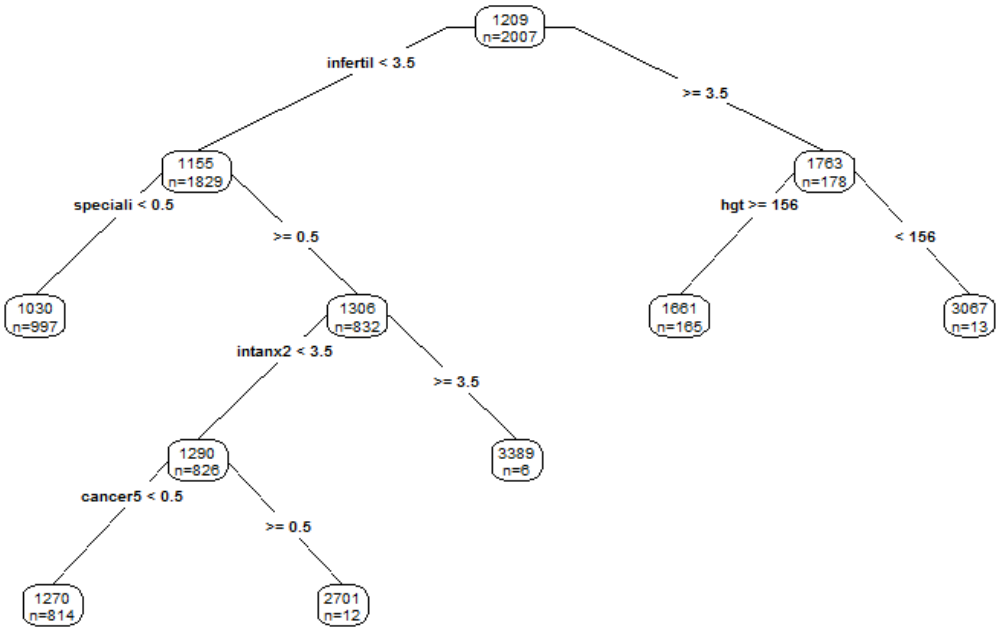
		($37,000 - $51,999 annually) 7= $1,000 - $1,499 per week ($52,000 - $77,999 annually) 8= $1,500 or more per week ($78,000 or more annually) 9= Don't know 10= Don't want to answer
Accessme	Thinking about your own health care, how would you rate the following: Access to medical specialists if you need them	1= Excellent 2= Very good 3= Good 4= Fair 5= Poor 6= Don’t Know
ICU	Did baby require special care?	1= Yes 0= No
Elective	Elective caesarean	1= Yes 0= No
Stillbth	Stillbirth	1= Yes 0= No
prevlbw	Previous low birth weight baby	1= Yes 0= No
Education	Highest qualification completed	1= No formal qualifications 2= School certificate (Year 10 or equivalent) 3= Higher School Certificate (Year 12 or equivalent) 4= Trade/apprenticeship (eg Haridresser, Chef) 5= Certificate/diploma (eg Child Care, Technician) 6= University degree Higher University degree (eg Grad Dip, Masters, PhD)

oftendri	How often do you usually drink alcohol?	1= I never drink alcohol 2= Less than once a month / I drink rarely 3= Less than once a week 4= On 1 or 2 days a week 5= On 3 or 4 days a week 6= On 5 or 6 days a week 7= Every day
Mosemo	Grouped Mean value of MOS scale values for Emotional/Informational Support. Higher scores for subscales and the index indicate more social support.	1= All of the time 2= Most of the time 3= Some of the time 4= None or a little of the time
Accessfe	Thinking about your own health care, how would you rate the following: Access to a female GP	1= Excellent 2= Very good 3= Good 4= Fair 5= Poor 6= Don't Know
Seifaocc	SEIFA index of Education and Occupation	Continuous (higher score indicates more education)

6.3.2.1 Public CART results - small

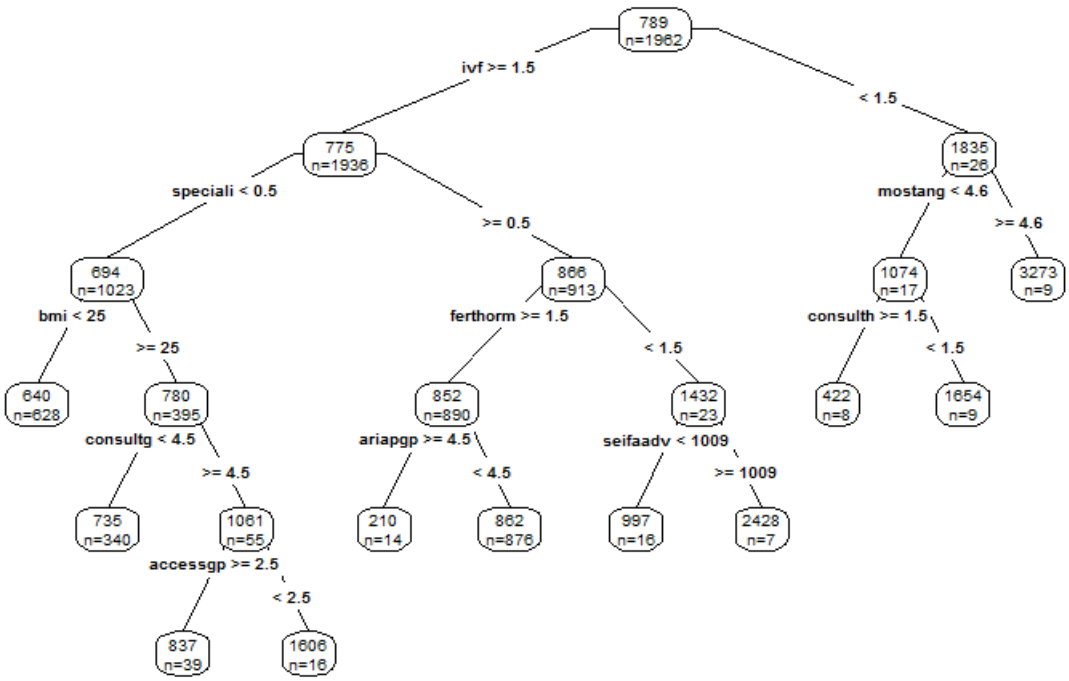
The regression tree model for total public costs (Figure 5.15) selected infertility (*infertil)* as the primary variable to split the tree, this split predicting that women who have had problems with or sought treatment for infertility will have higher predicted costs. This result makes sense as the Medicare services associated with infertility and the treatment thereof are expensive. Considering further splits of women who did not have issues with infertility (there is inadequate data in the infertility node to reliably split the tree further on that side), specialist use (*speciali)* appears to be important, followed by factors related to mental health (*intanx2).* Unsurprisingly, the tree model predicts that specialist use will increase average costs, and also that mental health factors will also have an adverse impact on cost.

Figure 5.15: Public Total CART results



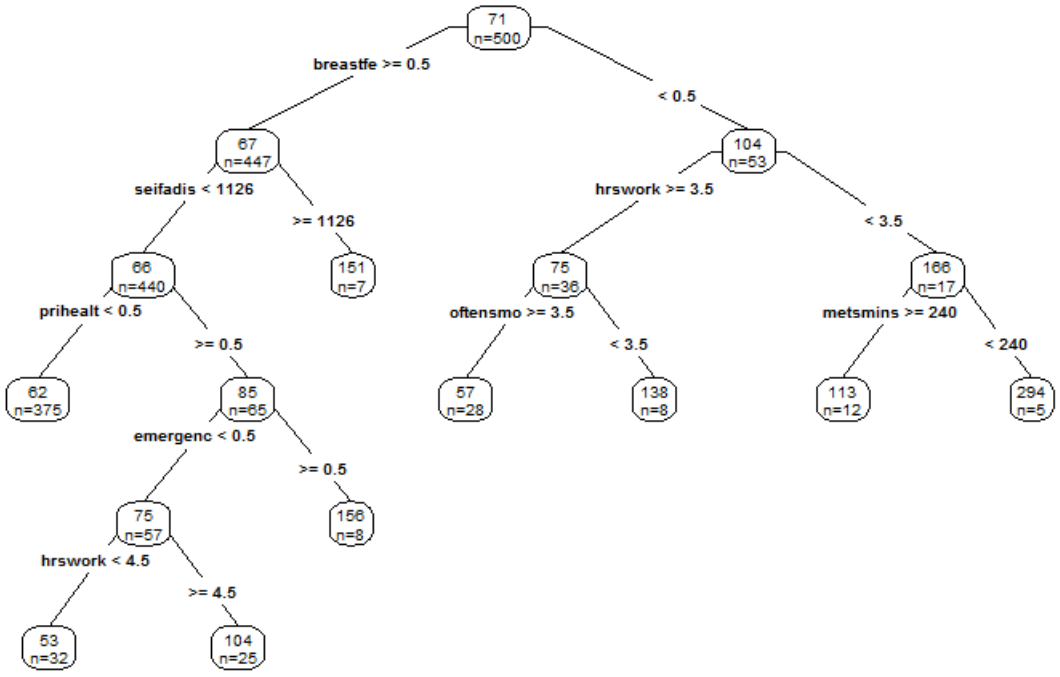
The primary split of the antenatal regression tree (Figure 5.16) also relates to infertility, but more specifically to whether or not the woman used IVF (*ivf*). Specialist use was the next major split of the tree for women who used IVF, with those that use specialists predicted to be more costly than those that do not. These splits were consistent with the findings in the total regression tree, an unsurprising outcome as antenatal costs dominate the total. Fertility hormone (*ferthorm*) use was the next split for those women who chose to see specialists, and BMI (*bmi*) was the next split for the women who did not see specialists. The impacts of these factors were also not surprising with higher BMI resulting in higher costs and fertility hormones also resulting in higher costs as women with these conditions have the potential to require more care during pregnancy.

Figure 5.16: Public Antenatal CART results



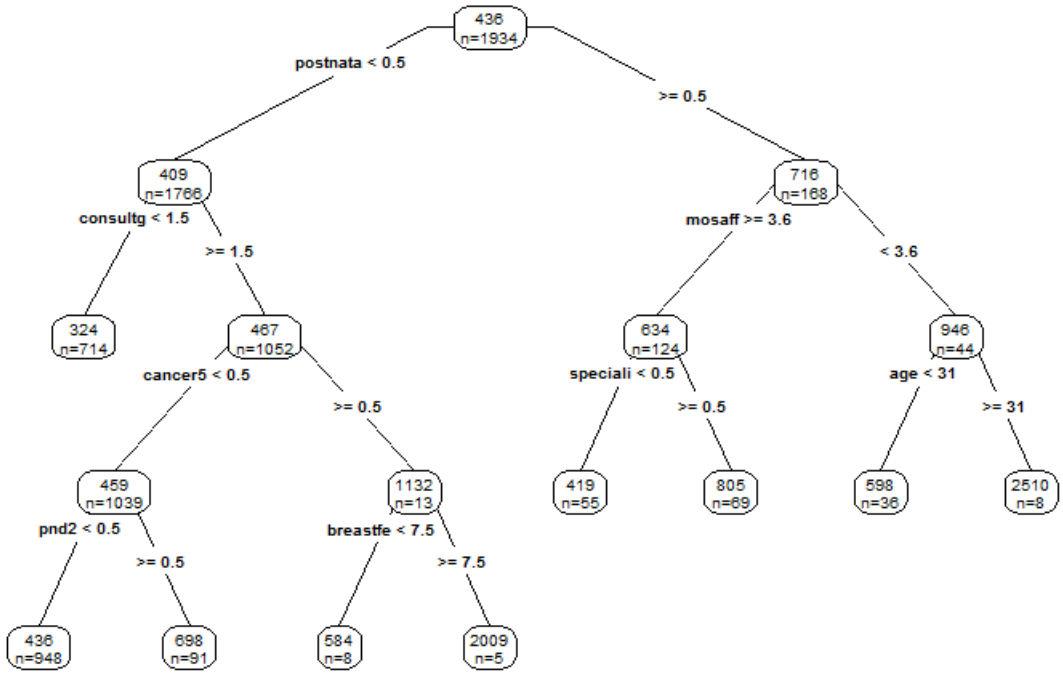
There is very little data contributing to the public delivery regression tree model (as public delivery is predominantly a hospital cost with little contributing to out-of-hospital costs) as shown in Figure 5.17, and thus the regression tree approach was considered too variable to interpret reliably.

Figure 5.17: Public Delivery CART results



For the postnatal regression tree model (Figure 5.18), postnatal depression (*postnatal*) was the primary split of the regression tree, with women who had experienced postnatal depression costing more than those that did not. Of the women that did not have postnatal depression, how frequently they consulted a GP (*consult*) was the next split of the tree, with more GP visits resulting in higher costs.

Figure 5.18: Public Postnatal CART results



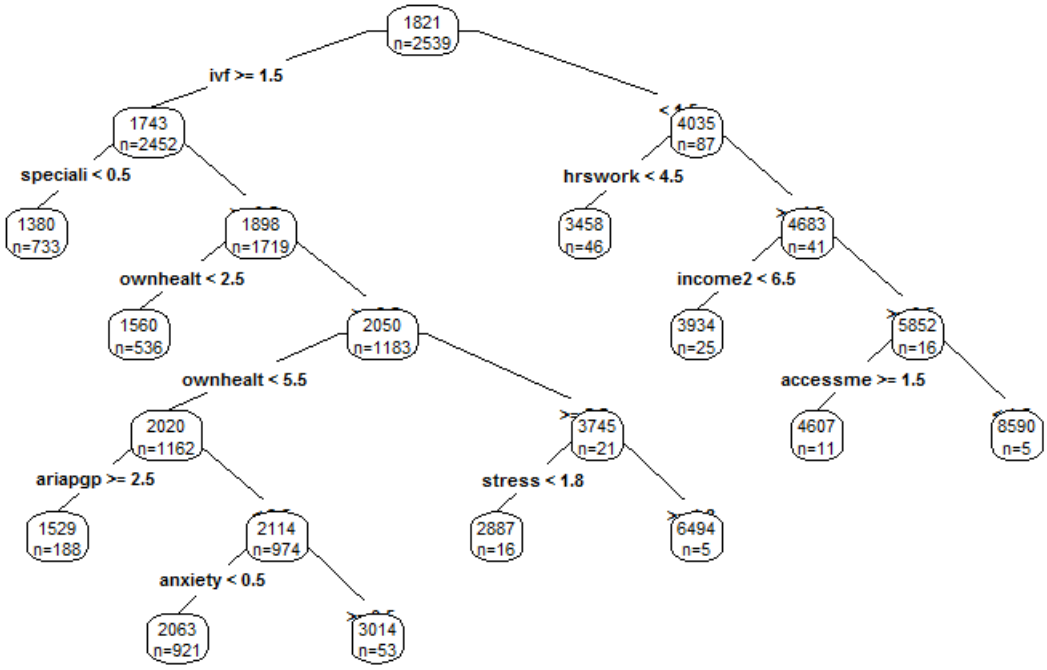
Overall, for the public data, the regression tree approach identified issues with fertility as dominant risk factors for cost, with specialist use also being a recurring feature driving higher costs. Interestingly, mental health factors were another theme that emerged from the tree modelling exercise as a key driver of costs.

6.3.2.2 Private CART results - small

The regression tree model for total private costs (Figure 5.19) selected IVF as the primary variable to split the tree, and predicts that women who have had IVF have a much higher average cost than women who haven't had IVF. This result makes sense intuitively, as the Medicare services associated with IVF are costly procedures. Considering further splits of women who did not have IVF (the IVF node was too small to further split), specialist use was important, followed by factors related to mental health (*ownhealt, stress, anxiety*). First, specialist use increases the average

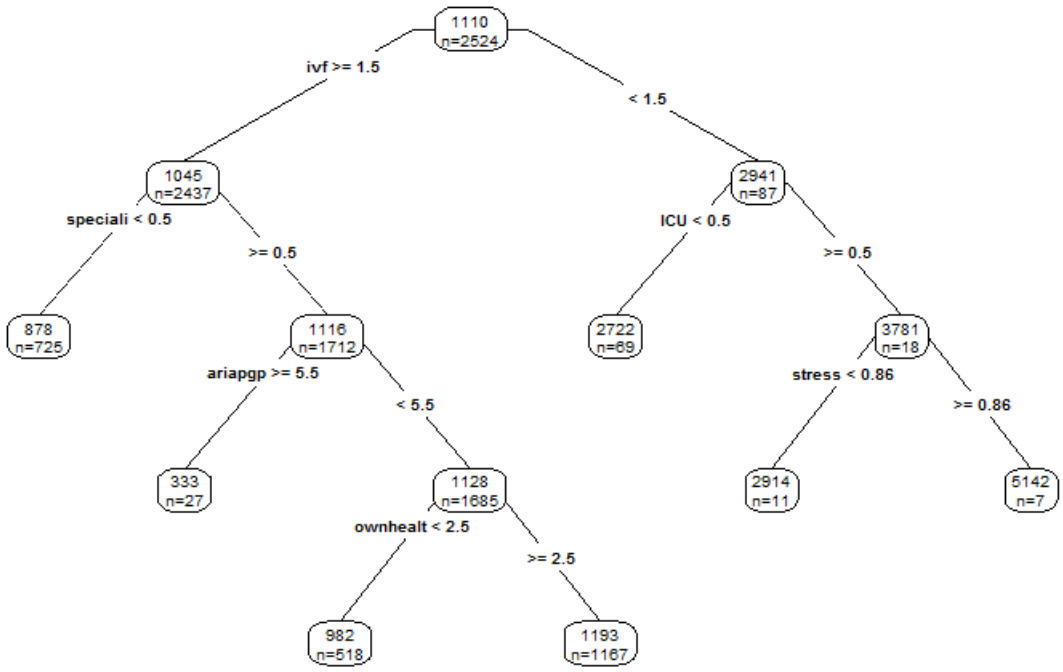
cost and this also makes sense intuitively as specialist services are more costly than non-specialist services. The factors related to mental health all suggest women who have issues with mental health have higher costs. There were many similarities between these results and the results of the public regression tree, in terms of infertility related procedures and mental health being key factors in influencing costs.

Figure 5.19: Private Total CART results



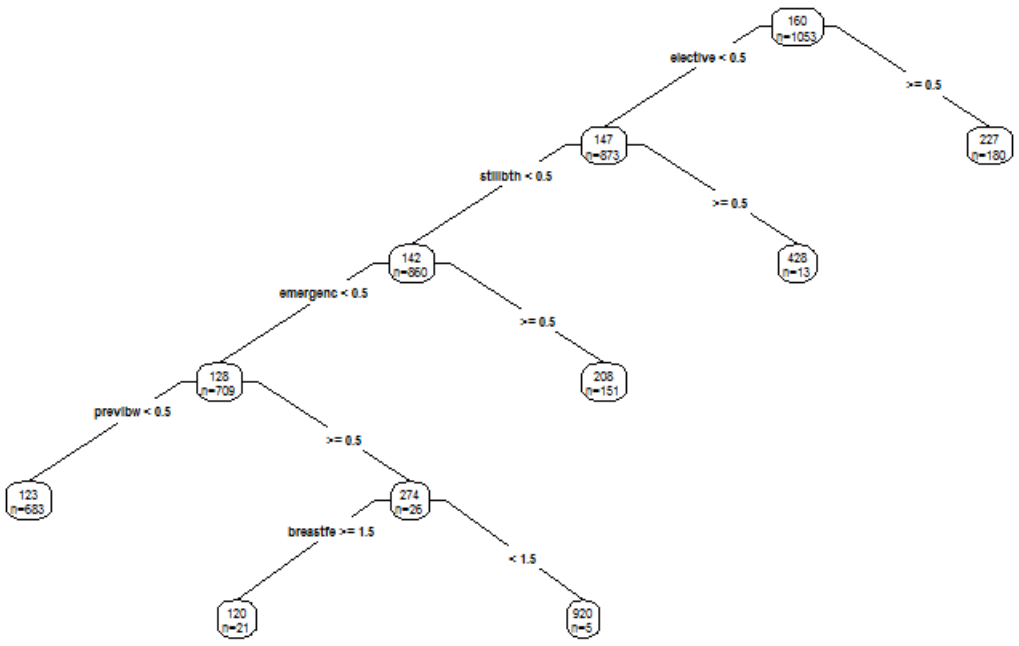
For antenatal costs (Figure 5.20), IVF was the primary split of the tree, followed by specialist use. This was not surprising as antenatal costs dominate the total costs and similar splits were seen in that model. Similar observations were noted with mental health factors to the total model with regard to stress about own health and the stress factor.

Figure 5.20: Private Antenatal CART results



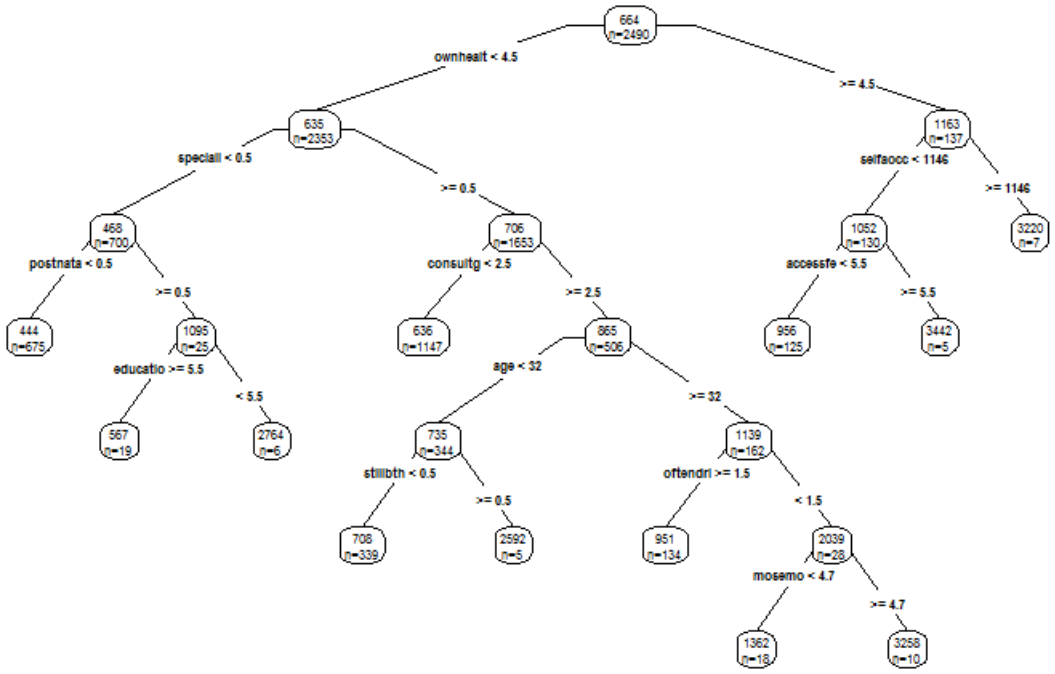
There was more data available within the private delivery context because of the involvement of obstetricians during the delivery period. The results of the tree modelling (Figure 5.21), show that caesareans (*elective, emergenc*) and adverse births (*prevlbw, stillbth*) were important splits of the tree, with both kinds of events leading to higher costs.

Figure 5.21: Private Delivery CART results



Mental health factors dominated the private postnatal regression tree (Figure 5.22), with stress about own health being the primary split of the tree. Where there was more self-reported own health stress, the costs tended to be higher. For the women with lower self-reported own health stress, specialist use and GP use were relevant cost drivers. Postnatal depression was selected to split the tree at the node for which women had lower self-reported own health stress and did not see a specialist.

Figure 5.22: Private Postnatal CART results



A similar process was undertaken for large costs, but there was little data available to fit reliable tree models. For completeness, these models are included in Appendix G.

6.3.2.3 Summary of CART results

Given the results of the CART modelling above (and additional factors identified in the literature review in Chapter 2), below summarises all the factors that were selected for inclusion in the formal parametric modelling phase (for small costs only). Note that the modelling process used to test these factors was described earlier in Section 3.6.3.

Table 5.8: Factors tested in GLM's (out-of-hospital costing)

Factor	Category
Aria + group (area of residence)	Demographic
Hours worked	Demographic
Income	Demographic
SEIFA indices	Demographic
Maternal age	Demographic
Education	Demographic
Marital status	Demographic
Occupation	Demographic
Rural, remote and metropolitan areas (RRMA) classification	Demographic
Age	Demographic
Breastfeeding	Health behaviour
Alcohol pattern	Health behaviour
Partner violence	Health behaviour
BMI	Health behaviour
Exercise	Health behaviour
Smoking status	Health behaviour
Marijuana	Health behaviour
Drug use	Health behaviour
Access to medical specialists	Health service use

Specialist use	Health service use
Access to female GP's	Health service use
Hospital visit for reasons other than pregnancy	Health service use
GP consultations	Health service use
Access to after-hours medical	Health service use
Access to GP that bulk bills	Health service use
Consult hospital doctor	Health service use
Private health insurance status - hospital cover	Health service use
Private health insurance status - ancillary cover	Health service use
Baby in special care	Obstetric
Elective caesarean	Obstetric
Emergency caesarean	Obstetric
Gas	Obstetric
Social support indices (MOS)	Psychological and physical health
Anxiety	Psychological and physical health
Stress about own health	Psychological and physical health
Stress	Psychological and physical health
Postnatal depression	Psychological and physical health

Postnatal anxiety	Psychological and physical health
Antenatal depression	Psychological and physical health
Antenatal anxiety	Psychological and physical health
Cancer	Psychological and physical health
Intense anxiety	Psychological and physical health
Endometrioses	Psychological and physical health
Hypertension	Psychological and physical health
Gestational diabetes	Psychological and physical health
Asthma	Psychological and physical health
Diabetes (type1, type2)	Psychological and physical health
Depression scale (cesd10)	Psychological and physical health
Life outlook index (lotr)	Psychological and physical health
Emotional abuse	Psychological and physical health

IVF	Reproductive
Previous adverse birth	Reproductive
Adverse birth	Reproductive
Stillbirth	Reproductive
Premature birth	Reproductive
Low birth weight birth	Reproductive
Previous stillbirth	Reproductive
Previous premature birth	Reproductive
Previous low birth weight	Reproductive
Infertility	Reproductive
Fertility hormones	Reproductive
Terminations (abortions)	Reproductive
Height	Other
Year	Other

6.3.3 Total cost GLMs - small

The regression tree approach provided valuable guidance as to an initial set of variables to include as part of a model selection process for more familiar parametric models for cost. Using the factors selected in the CART models above, generalised linear models relating cost and the other covariates within the data were fit, assuming a Gamma error distribution and log link. Results reported at significance level less than 0.1% are shown below and discussed briefly but more in-depth discussions are in Section 5.4. This significance level was selected due to the large volume of

variables being analysed and the aim of producing parsimonious models. Model checks including a model re-fit using a different error distribution and backward stepwise selection methods for significance of factors are included in Appendix H for some models. These checks showed that the significance levels were appropriate and the methods adopted were robust to these changes.

6.3.3.1 Public GLM results

For the public antenatal model (Table 5.9) there were many similarities with the significant cost risk factors and the factors seen in the regression trees. Factors related to infertility and IVF were significant as were mental health factors, such as intense anxiety (*intanx2*). These results showed that a woman who has had treatment for infertility and issues with mental health will cost significantly more than those who haven't experienced these issues during the antenatal period. The GP use (*consultgp2*) was also a significant factor, a result which was not surprising as women in the public maternity care system are more likely to see their GPs over specialists for their antenatal care. Area of residence (*ariapgp)* was also a significant cost risk factor, which could be an indicator of access to services (as more rural areas indicate lower costs).

Table 5.9: Public Antenatal GLM results

Coefficients	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	7.158	0.304	23.56	0.000
Ariapgp	-0.077	0.021	-3.66	0.000
Infertility	0.137	0.031	4.40	0.000
Ivf	-0.559	0.135	-4.15	0.000
intanx2	0.164	0.038	4.38	0.000
consultgp2	0.084	0.013	6.52	0.000

The public delivery case is shown in Table 5.10. As noted before, there was very little data available for this modelling exercise, as the cost in this case was predominantly a hospital cost. However, adverse birth (*ab*) was found to be a significant factor in this case, as it was in hospital costing.

Table 5.10: Public Delivery GLM results

Coefficients	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	4.220	0.046	92.82	1.18e-312
Ab	0.443	0.159	2.78	0.006

Table 5.11 shows the results of the public postnatal model. Mental health factors stood out in this model (*postnataldepress, ownhealthstress and anxiety*), and they were also evident in the regression trees too. This finding was important because it provided useful insight into the relationship between mental health and cost during the long postnatal period. Adverse birth was also seen as a significant cost risk factor here, as was area and hospital visits for reasons other than pregnancy (*hospoth2).*

Interestingly, cancer (*cancer5*) was also a significant factor, and it was found to be significant in the equivalent hospital costing model as well.

Table 5.11: Public Postnatal GLM results

Coefficients	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	5.765	0.098	59.06	0.00E+00
cancer5	0.646	0.229	2.82	4.90E-03
consultgp2	0.073	0.014	5.25	1.75E-07
postnataldepress	0.411	0.085	4.85	1.33E-06
anxiety	0.364	0.114	3.20	1.40E-03
ariapgp	-0.148	0.025	-5.90	4.45E-09
hospoth2	0.273	0.094	2.91	3.67E-03
ownhealthstress	0.092	0.027	3.48	5.15E-04
Ab	0.242	0.087	2.79	5.25E-03

Table 5.12: Public Total GLM results

Coefficients	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	7.688	0.290	26.49	1.83E-110
cancer5	0.462	0.157	2.95	3.28E-03
consultgp2	0.092	0.013	7.25	1.04E-12
Infertility	0.132	0.032	4.17	3.44E-05
Postnataldepress	0.344	0.080	4.32	1.76E-05
Ivf	-0.503	0.129	-3.92	9.74E-05
Anxiety	1.288	0.286	4.50	7.84E-06
Ariapgp	-0.095	0.021	-4.59	5.24E-06
infertility:anxiety	-0.385	0.115	-3.35	8.56E-04

As the antenatal component dominates the total costs, the results when in modelling total cost (Table 5.12) were very similar to the results for the antenatal period alone, however, the mental health factors were more prominent (as they were also in the postnatal model as well).

6.3.3.2 Private GLM results

There were some similarities between the private (Table 5.13) and public antenatal model (Table 5.9) in terms of the significance of IVF, area of residence, GP use and mental health factors; however there were also a number of key differences. Specialist use and elective caesareans (*electivecaesar*) were unsurprisingly significant here, but were absent in the public model. There was evidence to show increases in elective caesarean delivery rates over time in Figure 2.5 (However, this data were not split by public and private) and the result here suggested that even the antenatal costs for these women were higher as well. It is however likely that private patients are more able to request elective caesareans compared to public patients as their main care providers are specialists. Diabetes (*type1diab*) is well-known as a problematic condition during pregnancy but was also only significant in this model. Finally, the mental health factors that were significant in this case were different to those found significant in the public model (stress about own health and anxiety compared to intense anxiety in the public model).

Table 5.13: Private Antenatal GLM results

Coefficients	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	8.714	0.136	64.30	0.00E+00
Ariapgp	-0.178	0.013	-13.59	8.34E-40
Ivf	-0.966	0.062	-15.59	5.24E-51
Ownhealthstress	0.071	0.017	4.26	2.20E-05
specialist5	0.158	0.032	4.91	1.02E-06
Anxiety	0.183	0.066	2.77	5.60E-03
electivecaesar	0.148	0.039	3.83	1.31E-04
consultgp2	0.0504	0.010	4.87	1.23E-06
type1diab	0.7937	0.203	3.91	9.73E-05

The results for the private delivery model (Figure 5.14) were more reliable and definitive than for the public model, as there were considerably more data available. As identified in the regression trees, both types of caesareans were significant cost risk factors, as were previous (*prevab*) and current adverse births (*ab*). Note current adverse births were the only significant factor in the public delivery model. Area of residence was the other remaining significant factor.

Table 5.14: Private Delivery GLM results

Coefficients	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	4.973	0.082	60.72	0.00E+00
Electivecaesar	0.513	0.109	4.69	3.16E-06
Emergencycaesar	0.454	0.117	3.89	1.07E-04
Prevab	0.574	0.157	3.66	2.69E-04
Ab	0.449	0.126	3.57	3.76E-04
Ariapgp	-0.118	0.037	-3.21	1.37E+00

The private postnatal model (Table 5.15) had similar characteristics to the public postnatal model (Table 5.11) in that mental health factors (such as postnatal depression, anxiety and stress about own health) were prominent in both models. Area, GP use and adverse births were also significant in the private model. However, specialist use, endometriosis and whether the baby was breastfed or not were absent from the public models. Endometriosis is a condition relating to fertility and women with private health insurance may have tended to seek treatment for this condition more often than those that do not have private cover. The significance of breastfeeding (*breastfed2*) was an interesting discovery, and the results showed that the longer a woman breastfed, the lower the cost.

Table 5.15: Private Postnatal GLM results

Coefficients	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	6.130	0.123	49.91	0.00E+00
consultgp2	0.089	0.016	5.75	1.03E-08
specialist5	0.335	0.051	6.63	4.23E-11
ownhealthstress	0.137	0.026	5.23	1.88E-07
anxiety	0.431	0.114	3.79	1.53E-04
ariapgp	-0.162	0.021	-7.65	3.15E-14
breastfed2	-0.339	0.087	-3.89	1.03E-04
endometriosis	0.350	0.107	3.28	1.05E-03
postnataldepress	0.207	0.078	2.67	7.67E-03
ab	0.229	0.082	2.80	5.08E-03

As seen in the public models, the model for total cost (Table 5.16) most closely resembles the antenatal and postnatal models as these periods dominate in terms of contributions to total cost. Mental health factors, GP and specialist use, elective caesareans and IVF were all significant cost risk factors in influencing total cost.

Table 5.16: Private Total GLM results

Coefficients	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	7.998	0.249	32.08	9.69E-173
Anxiety	0.274	0.071	3.87	1.12E-04
Ivf	-0.423	0.124	-3.40	6.84E-04
ownhealthstress	0.092	0.018	5.26	1.65E-07
specialist5	0.212	0.034	6.28	4.52E-10
electivecaesar	0.166	0.041	4.07	4.98E-05
type1diab	0.616	0.212	2.90	3.75E-03
Ariapgp	0.217	0.137	1.58	1.14E-01
consultgp2	0.073	0.011	6.65	4.12E-11
Ab	0.168	0.053	3.15	1.64E-03
ivf:ariapgp	-0.204	0.070	-2.93	3.46E-03

6.3.3.3 Bi-monthly postnatal period analysis

In order to understand how postnatal costs developed over the one-year postnatal period, models were also fit to evaluate the effects of the covariates on costs for each bi-monthly interval following delivery. Table 5.17 and Table 5.18 show which cost risk factors were significant at each interval for both private and public models respectively. Full results of the GLMs are provided in Appendix I.

Table 5.17: Private bi-monthly postnatal models

Significant cost risk factors	Month following delivery					
	2	**4**	**6**	**8**	**10**	**12**
Adverse birth	√	√	√	√	√	√
Stress about own health	√	√	√	√	√	√
Area	√	√	√	√	√	√
Specialist use	√	√	√	√	√	√
Anxiety		√	√	√	√	√
Breastfed baby		√	√	√	√	√
GP use			√	√	√	√
Postnatal depression			√	√	√	√
Endometriosis					√	√

Table 5.18: Public bi-monthly postnatal models

Significant cost risk factors	Month following delivery					
	2	**4**	**6**	**8**	**10**	**12**
Adverse birth	√	√	√	√	√	√
Stress about own health		√	√	√	√	√
Area		√	√	√	√	√
GP use			√	√	√	√
Postnatal depression			√	√	√	√
Cancer					√	√
Hospital (other)					√	√
Anxiety						√

It was clear that for each of private and public postnatal cost models, there were more factors that significantly affected cost as time progressed; however, this could be an artefact of there being more data available for later months. Notwithstanding this possibility, the results of the earlier months were still considered reliable despite having less data involved in the fits, and these results provided important insights on the cost risk factors in the initial stages after the birth of a baby.

Adverse births, stress about own health and area were all significant factors that impact on cost from the early postnatal stages for both private and public cases. This finding highlighted how important these risk factors were on cost at every stage in the first postnatal year. These results also showed that women had concerns about

their own health following the delivery of their baby from very early on, and they were also likely to be higher cost patients across all months if they had experienced an adverse birth.

For the private case, specialist use was significant from early postnatal stages onwards, suggesting that women were still seeing their obstetricians and other specialists postnatally – a practice that increased their costs. Similarly, for the public case, GP use was significant from early postnatal stages onwards, and these women were using GPs to manage their postnatal care.

In terms of later stage conditions, for the private case, postnatal depression and endometriosis were two conditions that only became significant in later postnatal stages. Postnatal depression was evident by six months and endometriosis by ten months. These results suggested that these conditions took longer to have an impact on cost. For postnatal depression, this may be because women only seek costly treatments later in the postnatal period, particularly if the condition has developed to a stage where it has become severe and medical intervention became necessary. Endometriosis, on the other hand, is a condition related to fertility, and is suppressed during breastfeeding. The fact that this condition only impacts cost in the later stages of the postnatal period may be because breastfeeding has ceased and the symptoms have returned. In addition to this, the women might be beginning to plan for their next baby around this time, and therefore seeking treatment for endometriosis.

Similarly, for the public case, postnatal depression only became a significant risk factor for cost at the six-month mark, but cancer and going to hospital for reasons other than pregnancy were two factors that had an impact from the ten-month mark. Finally, anxiety was only evident in the twelve-month model. This differs from the

private model, where women were seeking treatment for anxiety earlier in the postnatal period.

These results provided overwhelming evidence about the impact on cost of mental health factors during the postnatal period and, more importantly, how these mental health factors developed over time in a way that significantly affected cost.

6.3.4 Frequency and severity GLMs - small

As described in Chapter 3, Section 3.6.1, it was useful to analyse the cost data by frequency and severity of the cost to further understand the underlying drivers of this cost. The frequency and severity were defined in this context as follows:

Frequency = number of services

Severity = average cost of the service = total cost / number of services

A similar process to the total cost modelling was adopted, first using regression trees as an exploratory technique to identify factors, and then formal parametric models in GLMs to model the cost. A negative binomial error distribution and log link GLM was used for the frequency model as the choice of a Poisson error distribution led to serious over-fitting. A Gamma error distribution with log link GLM was used for the severity model. Results reported at the 1% significance level are shown below. This significance level was selected due to the large volume of variables being analysed and the aim of producing parsimonious models.

The results of the GLMs are shown in Appendix J and only reproduced here where they were more complex and warranted more detailed explanation.

6.3.4.1 Public frequency and severity models

6.3.4.1.1 Antenatal model

The antenatal frequency (Table 5.19) and severity (Table 5.20) modelling showed that most of the factors found in the total cost model were the result of being high frequency factors (area, infertility, GP use) rather than high severity factors. IVF was the only factor from the total cost model that was significant in the severity model. There were, however, few other significant factors in both frequency and severity models that were not significant in the total cost model. The most notable significant covariate was postnatal depression, which was significant in both frequency and severity models. Intense anxiety was significant in the total cost model, but not in the frequency or severity models.

Table 5.19: Public antenatal frequency model

Coefficients	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	2.821	0.088	32.17	4.59e-227
ariapgp	-0.080	0.015	-5.20	2.04e-07
consultgp2	0.068	0.008	8.10	5.58e-16
infertility	0.089	0.020	4.39	1.15e-05
Bmi	0.011	0.003	4.29	1.82e-05
accessgpbb	-0.034	0.009	-3.91	9.36e-05
prihealthanc2	0.165	0.045	3.70	2.16e-04
postnataldepress	0.257	0.051	5.01	5.35e-07
specialist5	0.115	0.030	3.88	1.06e-04

Table 5.20: Public antenatal severity model

Coefficients	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	4.757	0.131	36.40	2.73e-173
Ivf	-0.591	0.063	-9.37	6.61e-20
postnataldepress	0.152	0.041	3.71	2.24e-04
mumstress	0.035	0.010	3.44	6.18e-04

6.3.4.1.2 Delivery model

The only significant factor in the total cost model was adverse births, and this effect was also evident in the severity model. In addition to this factor, emergency caesarean was significant in the severity model and hypertension was significant in the frequency model.

6.3.4.1.3 Postnatal model

The postnatal models showed that postnatal depression was significant in both the frequency and severity models. Area and anxiety were significant only in the severity model, but GP use, adverse births and specialist use were significant in the total cost model, arising from frequency effects rather than severity effects. Finally, stress about own health, hospital for other reasons and cancer were significant in the total cost models but not in the frequency or severity models.

6.3.4.2 Private frequency and severity models

6.3.4.2.1 Antenatal

All the factors from the total cost model were also significant in the frequency model and IVF and area were also significant in the severity model. There were a number

of additional factors that were significant in the frequency model and these are shown in Table 5.21.

Table 5.21: Private antenatal frequency model

Coefficients	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	-81.393	14.925	-5.45	4.94e-08
ariapgp	0.179	0.104	1.71	8.64e-02
consultgp2	-0.100	0.064	-1.56	1.20e-01
hyperten	0.170	0.0478	3.56	3.73e-04
Ivf	-0.300	0.107	-2.77	5.54e-03
Ownhealthstress	0.059	0.013	4.38	1.19e-05
specialist5	0.121	0.026	4.58	4.74e-06
type1diab	0.612	0.167	3.67	2.44e-04
yob	0.042	0.007	5.70	1.20e-08
electivecaesar	0.134	0.031	4.32	1.53e-05
education	-0.026	0.008	-2.95	3.13e-03
consultgp2:ivf	0.077	0.032	2.33	1.97e-02
ariapgp:ivf	-0.154	0.053	-2.90	3.70e-03

6.3.4.2.2 Delivery

Most of the factors from the total cost model (caesareans and adverse births) were significant in the frequency model; however, there were more factors in the frequency model (which were not significant in the total cost model) which are shown in Table 5.22. It is clear that the frequency effect dominates the total cost model, which contrasts to the public delivery models where the severity effect was more dominant.

Table 5.22: Private delivery frequency model

Coefficients	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	0.588	0.0862	6.81	9.44e-12
electivecaesar	0.393	0.0664	5.92	3.30e-09
emergencycaesar	0.370	0.0705	5.25	1.50e-07
prihealthanc2	0.407	0.0887	4.59	4.44e-06
Ab	0.407	0.0746	5.46	4.69e-08
hypertension	1.042	0.2585	4.03	5.53e-05
prihealthanc2:hypertension	-0.856	0.2721	-3.15	1.66e-03

6.3.4.2.3 Postnatal

With the exception of adverse births and endometriosis, all other factors from the total cost model were significant in the frequency model. Anxiety, area and specialist use were also significant in the severity model.

6.3.5 Total cost GLMs – large

A similar process to that described above was used to model large costs, particularly in terms of using regression trees to initially identify relevant factors and then GLMs to model the cost in terms of these covariates. Fitting of regression trees proved more challenging and the results were quite variable, likely because of the sparsity of data available for the large costs case. However, as these models were only used to identify potential initial factors, a tree model approach was still used and the results provided valuable candidate sets of variables for the GLM analysis. The results of the regression trees are shown in Appendix G. The results of the GLMs are shown below and discussed in more detail.

6.3.5.1 Public GLM results

For the public models (see Table 5.23-Table 5.26), there was little data available for large costs as the items that were selected to be included in large costs were mainly associated with private patients (for example, the items related to obstetric specialist services). Consequently, IVF was the only significant factor for both total cost and antenatal cost models. This was not a surprising outcome, as IVF is associated with high cost services, and patients who have undergone IVF are likely to be monitored more extensively during the antenatal period. As the antenatal period dominates the total cost, this outcome also applied to that model. GP use was the only significant factor for the delivery model, which makes sense because the women involved were public patients and therefore more likely to access GP services (as opposed to specialist services).

Fertility hormones and area were significant factors for the postnatal cost model. This finding suggested that those in major cities have a higher cost, potentially because of greater access to services compared to those in rural areas. The use of fertility hormones indicated a higher cost, which makes sense because women who have issues with infertility would be more likely to access (expensive) medical services to help with their fertility issues. The use of these hormones in the postnatal period may be suggesting women who struggle with infertility were already considering their next baby, hence the need to continue the use of these hormones during the one-year postnatal period.

Table 5.23: Public Antenatal GLM results

Coefficients	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	9.880	0.651	15.17	4.06E-42
Ivf	-2.110	0.330	-6.39	4.20E-10

Table 5.24: Public Delivery GLM results

Coefficients	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	4.706	0.148	31.73	2.76E-117
consultgp2	-0.104	0.049	-2.12	3.43E-02

Table 5.25: Public Postnatal GLM results

Coefficients	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	9.758	0.834	11.69	9.90E-21
Ferthorm	-1.923	0.417	-4.61	1.15E-05
Ariapgp	-0.592	0.148	-3.99	1.20E-04

Table 5.26: Public Total GLM results

Coefficients	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	10.040	0.745	13.47	5.11E-35
Ivf	-2.090	0.378	-5.52	5.83E-08

6.3.5.2 Private GLM results

The private antenatal model (Table 5.27) was considerably more complex than the public equivalent because of the tendency of large cost items to be associated with private patients. The significant factors included: IVF, GP and specialist use, the socio economic index for advantage, area and year of birth (of baby). The significance of year of birth reflected an inflationary impact of cost as it showed that the later years had a higher impact on cost than earlier years. As the underlying costs in the model had already been inflated to consistent money terms, this finding suggested that for large costs, there was some element of "superimposed inflation"; that is, inflation over and above what was expected through the AIHW Medicare services inflation which was used to inflate the underlying costs. The extent of this superimposed inflation can be estimated using the parameter in this model and is calculated at 13% p.a. Superimposed inflation is commonly seen in health costs in Australia and is largely due to improvements in health technologies over time (Armstrong & Dyson, 2014). However, in this case, it is representative of inflation on Medicare benefits for large cost items (particularly obstetric items) being more than what is expected using baseline Medicare Services inflation. Note that this observed superimposed inflation could also be a consequence of inflation on specialist provider charges, as the government was liable to pay a significant proportion of the provider charge when patients exceeded the safety net. This rising cost issue was identified as relevant for obstetrics in particular, hence, the introduction of the caps to obstetric benefits through the MBS to reduce the costs the government faced (Centre for Health Economics Research and Evaluation, 2011) which was also discussed in relation to historic changes in Medicare in Section

5.3.1.2. These caps only came into effect after the end of the period of the data used in this thesis.

The socio-economic index is constructed so that a higher score is indicative of more advantage. Therefore, the significance of this index as a factor suggested that those that were more advantaged will have higher antenatal costs. This result is possibly because these women were more likely to have private health insurance, both due to incentives set by the government and also through greater ability to pay. It is also likely that these women accessed more expensive services, whether it be through the public or private system, as they were in a position to pay for these services more readily (as there are higher out of pocket expenses associated with more expensive services even if they are offered through the MBS). Finally, the significance of the area variable suggested that those in remote areas attracted less cost, again possibly due to reduced access to medical services.

Table 5.27: Private Antenatal GLM results

Coefficients	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	-2.39E+02	2.87E+01	-8.31	2.24E-16
Ivf	-9.24E-01	9.20E-02	-10.04	5.80E-23
Ariapgp	-3.25E-01	2.67E-02	-12.18	1.60E-32
Seifaadv	6.63E-04	2.11E-04	3.14	1.74E-03
Yob	1.23E-01	1.43E-02	8.61	1.87E-17
consultgp2	-5.69E-02	1.59E-02	-3.57	3.65E-04
specialist5	2.99E-01	5.12E-02	5.83	6.79E-09

For private delivery costs (Table 5.28), caesareans (both emergency and elective) and specialist use were significant. This was a reassuring finding from this model, as

it was expected given the types of services that were included in the large costs (many were related to obstetric services such as delivery). As seen in the hospital costing, caesareans were associated with higher costs and require the services of specialists if using the private health care system in Australia.

Table 5.28: Private Delivery GLM results

Coefficients	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	5.583	0.065	85.51	0.00E+00
emergencycaesar	0.590	0.102	5.78	9.26E-09
Electivecaesar	0.265	0.092	2.87	4.16E-03
specialist5	0.208	0.074	2.80	5.19E-03

For private postnatal costs (Table 5.29), both types of caesareans, the socio economic index for advantage, and epidural use were significant. Similar comments to other private models apply here with regard to these significant factors; however, it is also important to note that these results showed that the impact on cost from caesareans and epidural continued post delivery into the postnatal period. This was possibly due to longer recovery times or more complex follow-up procedures required with these types of services.

Table 5.29: Private Postnatal GLM results

Coefficients	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	5.909	0.219	26.92	1.03E-117
Emergencycaesar	0.420	0.081	5.24	1.96E-07
Seifaadv	0.001	0.0002	2.60	9.46E-03
Epidural	0.266	0.054	4.89	1.19E-06
Electivecaesar	0.255	0.067	3.81	1.48E-04

Finally, the total cost model (Table 5.30) is dominated by the results of the antenatal model, but also includes both types of caesareans which were also found to be significant in the delivery and postnatal models.

Table 5.30: Private Total GLM results

Coefficients	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	4.59E+02	1.89E+02	2.43	1.54E-02
ariapgp	-2.51E-01	1.99E-02	-12.61	1.32E-34
ivf	-3.28E+02	9.64E+01	-3.40	6.83E-04
seifaadv	5.99E-04	1.57E-04	3.82	1.41E-04
yob	-2.24E-01	9.42E-02	-2.38	1.74E-02
consultgp2	-4.14E-02	1.19E-02	-3.50	4.88E-04
electivecaesar	2.22E-01	4.36E-02	5.09	4.09E-07
emergencycaesar	2.24E-01	4.91E-02	4.56	5.53E-06
specialist5	2.64E-01	3.81E-02	6.92	6.81E-12
ivf:yob	1.63E-01	4.80E-02	3.40	7.00E-04

6.3.6 Frequency and severity GLMs - large

The same process to study frequency and severity was used for small costs as for large costs (see Section 5.3.3.3). The results of the GLMs are shown in Appendix K and only reproduced here where they were more complex and warranted more detailed explanation.

6.3.6.1 Public frequency and severity models

The sparse data were a material issue for some periods when modelling frequency and severity for public cost models. This sparsity made convergence of model fits very difficult, to the extent that there were no models that successfully converged for the delivery period. This was not a major impediment to analysis, as the total cost model only identified GP use as a significant cost risk factor. For the antenatal period, IVF was found to be an important factor for severity, and area, access to medical specialists and year of birth were found to be significant factors for the frequency of services. It was clear that the severity factor dominated the frequency effect as in the total cost model only IVF was found to be significant. Thus, IVF patients tended to be high in average cost during the antenatal period, but low in frequency of service use for larger costs. The frequency factors were interesting as they were associated with access to medical services; if the access to medical specialists was poor, the frequency of service use was lower and, similarly, if the area was a major city the frequency of service use was lower compared to rural areas.

The postnatal severity model found the same significant cost risk factors as the total cost model (area and fertility hormones), suggesting that these factors drive total cost through their high average costs rather than through high frequency service use.

6.3.6.2 Private frequency and severity models

6.3.6.2.1 Antenatal models

The frequency and severity analysis for the private antenatal cost models (Table 5.31) showed that most of the total cost risk factors were significant because they corresponded to high average costs rather than high frequency service use. These factors were: IVF, year of birth, specialist use and socio-economic index of advantage. The only total cost risk factor that was significant from the frequency perspective was area, and showed the opposite relationship to the public antenatal model – that is, those in cities had a higher service use compared to those in rural areas. In addition to this, the antenatal frequency model also presented some other interesting factors: adverse births, access to medical specialists, epidural use, and specialist use:

Table 5.31: Private Antenatal Frequency GLM results (large)

Coefficients	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	2.378	0.0237	100.48	0.00E+00
epidural	0.135	0.0144	9.37	7.31E-21
ab	-0.170	0.0263	-6.47	9.91E-11
ariapgp	-0.049	0.0083	-5.89	3.91E-09
accessmed	-0.026	0.006	-4.23	2.36E-05
specialist5	0.047	0.016	2.91	3.61E-03

6.3.6.2.2 Delivery models

As seen for the private antenatal models, the severity models influence the total cost for the delivery period too – that is, both types of caesareans and specialist use were

high average cost services. Results are shown in Table 5.32: Private Delivery Severity GLM results (large).

Table 5.32: Private Delivery Severity GLM results (large)

Coefficients	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	5.583	0.065	85.51	0.00E+00
emergencycaesar	0.590	0.102	5.78	9.26E-09
electivecaesar	0.265	0.092	2.87	4.16E-03
specialist5	0.208	0.074	2.80	5.19E-03

In addition to this finding, emergency caesareans were also a significant factor in the frequency model, a result that can be interpreted as women who had emergency caesareans having a higher frequency of service use during the delivery period. This outcome makes sense as women who were in this situation were more likely to have had complications that would have resulted in the greater use of more complex – and therefore expensive – services.

6.3.6.2.3 Postnatal models

As seen in both the antenatal and delivery cost models, the severity models influence the total cost for the postnatal period too – that is both types of caesareans, socio-economic index for advantage and epidural use were high average cost services. Results are shown in Table 5.33.

Table 5.33: Private Postnatal Severity GLM results (large)

Coefficients	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	5.909	0.219	26.92	1.03E-117
emergencycaesar	0.420	0.080	5.24	1.96E-07
seifaadv	0.001	0.0002	2.60	9.46E-03
epidural	0.266	0.054	4.89	1.19E-06
electivecaesar	0.255	0.067	3.81	1.48E-04

In addition to this finding, epidural use was also a significant factor in the frequency model, a result that can be interpreted as women who had epidurals requiring more services and those services being of higher average cost in the postnatal period.

As discussed for the total cost models these factors may be evident in the postnatal period because of extended recovery times and/or more complicated follow up procedures that have a material impact on cost. The breakdown into frequency and severity shows that most of the cost impact comes through the use of high average cost services for large costs rather than high service use.

6.4 Discussion

Overall, the out-of-hospital cost was driven largely by whether the woman had public or private health insurance. The distribution of costs varied materially for both systems. Furthermore, there were a number of costs relating to obstetrics, anaesthesia and IVF that were particularly large and more conducive to a separate analysis, especially IVF, as it swamped the effects of other variables. Once these large costs were removed, the most common significant cost risk factor across most models (for both public and private) was related to mental health. This included separate factors

such as anxiety, intense anxiety, postnatal depression and stress about own health. However, IVF and/or infertility were the variables that had the greatest impact on cost, a finding which was not surprising given how expensive procedures related to these services are. Specialist use and GP use were also common in the private and public models, respectively, which makes sense because private patients were more likely to use the services of specialists while public patients were more likely to use the services of GPs during their antenatal and postnatal care. These factors were all commonly found significant in both the total models and antenatal models.

During the delivery period, elective and emergency caesareans were significant for private models and adverse births were significant for both private and public models. It was not surprising that adverse births and caesareans were significant in these cases as they often involve complex procedures, and are therefore possibly more susceptible to complications. Finally, in the postnatal period the mental health factors became prominent again. Other health conditions such as cancer (in public models), type 1 diabetes and endometriosis (in private models) were also significant in some models in both the antenatal and the postnatal periods.

Interestingly, adverse births were only significant in the delivery and postnatal periods which relate to periods in close proximity to the adverse birth event. These results showed that adverse births do have a significant impact which becomes apparent around the time the birth event has occurred (as labour was also included in the delivery period), but that the cost impacts extend into the period following the birth of the baby. Also, IVF was not significant in the delivery or postnatal period suggesting women who have these procedures become like other women in terms of cost once they have had their baby. During the antenatal period however these

women have much higher costs than those that do not have IVF, possibly because they are being monitored more closely during their pregnancies.

The study of the development of cost risk factors over the postnatal period revealed that adverse births, stress about own health and area were factors that were consistently impacting on cost throughout the one-year postnatal period. There were cost impacts from specialist care for private patients for the entire postnatal period, while the public models showed that GP care was used more in the latter half of the postnatal period. Finally, other mental health factors such as anxiety and postnatal depression showed interesting impacts on cost as the postnatal period progressed – postnatal depression developed into a significant cost risk factor by 6 months for both public and private; but treatment for anxiety was only significant for public costs close to the end of the postnatal period, which contrasts with the private costs case, where it was found significant much earlier in the postnatal period.

Interesting results also emerged once these models were considered in a frequency and severity context. Most of the factors discussed above were significant for frequency models but severity models showed different results. Anxiety, IVF and specialist use (for private only) were the three consistent factors that were significant in severity models. IVF and specialist use were prominent in frequency models too, suggesting they were high frequency and high average cost variables. In summary, most of the other factors seen in the total cost modelling were high frequency but not high severity.

In the models for large cost items, the results were quite different to all models discussed above. While specialist and GP use appeared frequently again, they were more equally represented in both public and private models. Socioeconomic factors

associated with advantages and disadvantages were more relevant to the large cost context, possibly highlighting that ability to pay was highly relevant to the seeking and subsequent provision of some large cost services. Area was also a significant factor, possibly again linked to broader issues related to access to specialised medical services. Finally, elective and emergency caesareans and epidural use were the most important variables across many of the models fit related to large cost items. This finding also makes sense as these are known to be very costly procedures.

Given these results, it was clear that area and socioeconomic factors significantly affect the cost variation for large costs. In addition to this, IVF, GP use, specialist use and caesareans were also important, particularly for private costs. This suggests that large costs were likely to be driven mainly by woman's ability to pay and the provision of certain types of services (GP and specialists) and procedures (caesareans and IVF). These services and procedures also tend to be quite expensive, so perhaps only those who could afford them were seeking them. While many of these services and procedures were seen in the small cost models, they shared influence on cost with many other factors. In the large cost models, however, no other significant factors emerged. In addition to these observations regarding the cost risk factors, it was also evident that were was superimposed inflation effects in large costs for private antenatal periods, a phenomenon which was likely driven by higher than predicted specialist-related costs over time.

Unfortunately, (as seen in hospital costing), there were few comparisons that could be made with these results to previous research in the area due to the fundamental differences between this study and previous studies. No prior studies considered out-

of-hospital costs in the same way as they were considered in this thesis, but these results broadly agreed with all previous research in that the maternal health system costs for women with adverse birth outcomes were higher than for those without adverse birth outcomes (Chollet et al., 1996; Gilbert et al., 2003; Gold et al., 2013; Luke et al., 1996; Mistry et al., 2013; Petrou & Khan, 2012; Ringborg et al., 2006). These results also showed that this difference is statistically significant during the delivery and postnatal periods for both public and private cases.

This study also considered a more diverse selection of cost risk factors through the ALSWH survey, and has therefore been able to link factors such as mental health and other health behaviours to increased costs, a feature that other studies have been unable to summon. These findings were important because they provided a comprehensive picture of what the most important drivers of the maternal out-of-hospital costs were. It also showed the importance of considering out-of-hospital costs across all three sub-periods of the perinatal period, by small and large costs and by public and private cases separately as the results varied considerably between each of these segments and the drivers of cost were different depending on the segment under consideration. The breadth of the factors studied and the modelling techniques ensured that only the most significant factors would be selected for further consideration from a public policy perspective.

6.5 Conclusion

Many maternal cost risk factors have been identified for both public and private models across the three periods of care studied. There were many similarities between the relevant cost risk drivers for cost for private and public patients, such as IVF, mental health factors and adverse births, but there were also a number of

critical differences in terms of the use of specialists versus GPs, significance of caesareans in private and the temporal development of mental health factors over the postnatal period. Large cost items were also a much more significant issue for the private case; with socioeconomic factors, IVF, caesareans and anaesthesia critically impacting on the costs. There was also evidence of superimposed inflation on private antenatal costs. To summarise, the inherent differences between the two systems of health care funding and pathways of pregnancy have inevitably led to differences in the provision of maternal health care, and consequently affecting cost risk factors, for both small and large costs.

Antenatal and postnatal models were relatively more important in cost considerations in comparison to the delivery cost models as they represented the vast majority – over 90% – of the total cost (the opposite of the situation for hospital costing). IVF use was a significant factor antenatally for both private and public, but the models suggested that the cost impact vanishes following the birth of the baby. Adverse births, on the other hand, were a significant factor in both public and private models following the birth of the baby. Finally, there was a clear theme that emerged from the models fit in terms of the significance of mental health factors on cost. These factors included anxiety, intense anxiety, postnatal depression and stress about own health, and were especially apparent in the postnatal models (some were, however, also present antenatally). These factors will be addressed in the next chapter from a health policy standpoint due to their consistent presence as significant factors in these models.

7 Discussion

The first two aims of this thesis were to quantify and understand the maternal health system cost differentials and cost risk factors, with particular focus on women who have experienced adverse birth outcomes. The final aim was to use the results of the quantitative analysis to make recommendations for health policy in this area so that resources can be utilised in a more cost-effective manner, and also be targeted at women who are more at risk.

This chapter draws together the findings of the study, with particular focus on the two costing studies. Also discussed are the potential health policy initiatives. The use of quantitative analysis to inform policy in this area has not been directly covered in previous literature, with the exception of Chollet et al. (1996) who concluded their quantitative analysis with health policy recommendations. The recommendations from this paper (discussed in Section 2.2.5) included initiatives such as a diabetes and pregnancy management program and an emphasis on better physical and mental health management. Policy makers are increasingly recognising the importance of evidence-informed policy, particularly through the use of evidence based on linked data (Ellis et al., 2013; Johar et al., 2012), and the quantitative analysis in this thesis can be used to inform cost-effective maternal health care policy. This chapter will consider evidence-informed health policy processes when recommending policy initiatives.

First, however, it is worth reviewing the key results of the thesis and how these results will fit into the policy discussion. Both costing studies showed that the mean maternal health system cost differentials were substantial; with mean cost differentials of 23% and 27% for hospital and out-of-hospital costs, respectively.

These figures cannot be directly compared to those from other literature because of differences in methodology and data; however, they are broadly in line with the figures seen in other papers (Gilbert et al., 2003; Gold et al., 2013; Luke et al., 1996; Ringborg et al., 2006) where cost differentials were in the range of 10-250% depending on the type of adverse birth. Specifically Gold et al. 2013 reported a mean maternal cost differential for stillbirths of 10% and Ringborg et al. 2006 reported a mean maternal cost differential of 36% and 47% for premature and low birth weight, respectively (see Section 2.2.6).

This thesis also considered the statistical significance of the maternal costs of adverse births by analysing this factor within a multivariate modelling framework taking into account a large number of other potential cost risk factors in the six broad categories of demographics, health service use, health behaviours, psychological and physical health, obstetric and reproductive factors. Adverse births were indeed a statistically significant cost risk factor even in the presence of other cost risk factors in a few key areas: hospital delivery periods for public patients and out-of-hospital delivery and postnatal periods for both public and private cases. The findings of this study showed that adverse births were only statistically significant from a cost perspective around the time of the occurrence of the adverse event (that is, during the delivery period and following into the postnatal period). The predicted cost differentials were also lower than the simple mean cost differentials reported earlier as other cost risk factors also explain the variation in cost. This highlights the importance of considering the cost in a multivariate context as this approach enables a much more nuanced understanding of the actual impact of each risk factor on cost.

Conversely, this finding also showed that adverse births were **not** a significant cost risk factor for a number of different segments (and time periods) too. Firstly, it was not significant in the antenatal models for both private and public cases in both hospital and out-of-hospital models. This finding is not surprising for the hospital models because antenatal care is predominantly received out-of-hospital. For out-of-hospital costs, the absence of this factor suggested that other factors were more important in explaining the drivers of the cost in this period. Such factors included area, IVF, mental health factors, GP and specialist use. Interestingly, previous adverse births were not significant in the antenatal period. Secondly, adverse births were not significant for private patients in the hospital delivery model, suggesting factors such as age, IVF, mode of delivery and model of care using a private obstetrician (which were all statistically significant in this model) outweighed any impact adverse births may have had. Alternatively, adverse births may not be significant for private patients, as past research has shown that private patients were less likely to experience these types of outcomes (Robson et al., 2009). In any case, a better understanding of the differences between care pathways of private and public patients and their respective outcomes would be beneficial to understanding this result better and, therefore, understanding the policy implications around the public and private maternal health care system. Finally, adverse births were also not significant for the postnatal period of the hospital models, which was also not surprising given postnatal care is also predominantly received out-of-hospital. It was indeed significant in the postnatal period for out-of-hospital models for both private and public cases, a result that showed that once the adverse event had occurred women were in need of more health services and/or more expensive services. Note that it is difficult to provide direct comparisons of these results to previous studies as

those studies did not consider costs within the multivariate modelling framework and across perinatal sub-periods (with the exception of Gold et al., 2013, who only focussed on stillbirths).

In summary, the key cost risk factors varied across hospital costs and out-of-hospital costs and by perinatal sub-period. For hospital costs, they were mode of delivery, IVF, specialist use, private health insurance use, diabetes, area of residence, adverse births and smoking status. Smoking status will be considered further in this discussion as it is a modifiable risk factor and relatively well known in terms of its impact on health outcomes, so therefore more effective health policy can be suggested. There is more research recommended on the former risk factors, as more complexities arise in terms of their impact on maternal health system costs. In particular, mode of delivery, IVF and care pathways resulting from the mixed public-private maternity health care system are three areas on which further research should focus. The first area is selected here because it was a highly significant cost risk factor for many models in this thesis, in particular hospital costs for both public and private, and also private out-of-hospital models. There was also a number of unresolved issues discussed with regard to mode of delivery in this thesis, mainly concerning the rate of caesarean deliveries increasing over time, and insufficient data being available to understand the causes of these caesarean deliveries and corresponding increases (Australian Institute of Health and Welfare, 2014a). Further to this point and more importantly, the outcomes for the woman and the infant following a caesarean delivery should be assessed to ascertain if the caesarean delivery itself was necessary. While caesarean delivery is significantly more expensive than vaginal delivery, their use to improve maternal and infant outcomes may, in fact, reflect an efficient use of health resources, despite the overt cost

increase. However there currently are not enough data to accurately assess this question, and further research is recommended.

ART (IVF, in particular) was also another area where there were significant costs incurred (in both public and private antenatal out-of-hospital models and private hospital models), but the use of resources for these women could also result in better maternal and infant outcomes. Therefore, further research is warranted to test whether this is the case. Notably, IVF was a key driver of costs in the private hospital costing models, often swamping other factors. It was also found to be a low frequency but high severity factor, because it has a fairly low prevalence rate in Australia but the services associated with it are quite expensive. Further, women who have had ART have also been found to have higher rates of caesarean deliveries (Macaldowie et al., 2012), further increasing the associated cost. A more complete understanding of the complexities of the care of ART patients and how such factors drive these results would help in understanding whether they are indeed justifiable costs with improved outcomes for women. Ideally, a larger dataset of women who have undergone IVF is needed for such analysis.

Finally, care pathways for private and public patients, including the drivers of the take-up of private health insurance, should be considered further, as this factor was significant in the private hospital models. Furthermore, it was also found that the adverse births indicator was a significant cost risk factor for public patients but not private patients (in the hospital costing study). There are complexities with the take up of private health insurance in Australia, not only due to the possibility of adverse selection, but also related to the government's punitive tax regimes that strongly encourage people in certain demographics to take up private health insurance (that is,

those with higher incomes and younger people). These factors and the interrelationships between them are complex and warrant a more in-depth analysis with specific regard to maternal health care.

For out-of-hospital costs, the key cost risk factors were IVF, specialist use, GP use, private health insurance use, area of residence, adverse births and mental health factors (including anxiety, intense anxiety, postnatal depression and stress about own health). The last factor will be the focus of this discussion as it is a modifiable risk factor, and consistently significant across many of these models. As with hospital costing, there is more research recommended on the other factors before informed policy can be recommended. In particular (and related to the issue of take-up of private health discussed above), the care pathways appeared to have a significant impact on the out-of-hospital costs in both antenatal and postnatal periods. Specialist use was unsurprisingly more prominent in private models and, correspondingly, GP use was more prominent in public models. However private models also generally included GP use as well. Understanding how these types of services interact with each other and also their impact on maternal outcomes should be considered further as they are fundamental services in the context of the Australian maternal health care system and also clearly important drivers of the costs incurred.

It is also worthwhile noting that modifiable risk factors are often considered when discussing feasible health policy because these risk factors can be treated or controlled as opposed to non-modifiable risk factors that cannot be changed. The two risk factors identified for this discussion are modifiable risk factors. For example, smoking status is a modifiable risk factor because it is a health behaviour that can be positively influenced as a result of effective health policy. Mental health factors are

also modifiable risk factors, as they may be better avoided, managed or treated with appropriate health policy. Adverse births were intentionally not selected for further discussion here as they are not medical conditions, per se, and nor are they a health behaviour. Furthermore, adverse births represent a complex area because the actual causes of such births are still relatively unknown – for example, it is still unknown what causes a woman to go into labour prematurely, or what causes stillbirths (Cousens et al., 2011; Flenady et al., 2011; Howson et al., 2012; World Health Organisation, 2011), and further research has been called for to fill these knowledge gaps. Thus, adverse births are only considered in this discussion through the other cost risk factors identified (smoking and mental health factors) as they themselves are risk factors of adverse births as discussed in Section 2.3. These two risk factors will be discussed in turn within the context of the current maternal healthcare system in Australia (see Section 1.1.1) with consideration given to recent research and emerging health policy in the area. Before commencing the discussion on these risk factors, a brief background of evidence-informed policy is given to set the scene on how these policies may be taken forward.

7.1 Evidence-informed health policy

The World Health Organisation (WHO) describes evidence-informed health policy as follows: "Evidence-informed health policy making is an approach to policy decisions that aims to ensure that decision making is well-informed by the best available research evidence. It is characterised by the systematic and transparent access to, and appraisal of, evidence as an input into the policy-making process" (Oxman, Lavis, Lewin, & Fretheim, 2009) (p1). This paper also stated that the overall process of policymaking is not assumed to be systematic or transparent but

within this process, systematic processes should be used to ensure relevant research is identified, appraised and used appropriately. These processes should be transparent so that others can understand what research evidence was used to inform policy decisions as well as to make judgements about the evidence and its implications. Evidence-informed policymaking helps policymakers gain an understanding of these processes (Oxman et al., 2009).

Given the principles of evidence-informed health policy, this chapter considers all the evidence from this thesis including: background material on the Australian maternal health system and adverse births in Chapter 1; the literature review in Chapter 2; and the results of the two costing study analyses in Chapters 4 and 5. This evidence is combined with any other relevant research in maternal health policy to form the basis of the following health policy discussion.

7.2 Smoking status

The results of the modelling showed that smoking status was a significant factor in the public hospital model. Public hospital cost was the most important component from both costing studies because it represented over 80% of the total hospital cost and it was also reported that hospital costs themselves represented over 90% of the expenditure in maternal health in Australia (Australian Institute of Health and Welfare, 2010). The significance of this cost risk factor was not a surprising finding as it is well known that there is an association between smoking in pregnancy and adverse birth outcomes (Flenady et al., 2011; Hogberg & Cnattingius, 2007; Odendaal et al., 2008; Olsen et al., 1991; Wisborg et al., 2001). Note that this factor was based on questions in the ALSWH survey that asked how much a woman *currently* smoked (measured by the number of cigarettes per day), and therefore it

may not necessarily coincide with whether she smoked during pregnancy or not (as the response at the time of completing the survey may not correspond directly to the pregnancy period due to surveys occurring every 3 to 4 years). However, this factor does provide insight into the overall smoking health behaviour of the woman. It is also fair to say that this factor would be correlated with a factor that considered smoking during pregnancy. In terms of smoking during pregnancy, ALSWH studies showed that at least half the women who were smokers before pregnancy quit smoking during pregnancy, but 30% or more did not (Loxton & Lucke, 2009; JR Powers, McDermott, Loxton, & Chojenta, 2013). At present, there are no Australian national data available on smoking prevalence during pregnancy. Smoking data are collected through the perinatal data collections but the reliability and consistency of these collections vary widely by states and territories. There are also no nationally agreed data items on smoking during pregnancy in Australia (Paula Laws, Grayson, & Sullivan, 2006). There are data, however, that showed in 2006 the proportion of women who smoked while pregnant ranged from 13% in New South Wales to 29% in the Northern Territory (PJ Laws & Hilder, 2008). Overall, the prevalence of smoking in pregnant women in Australia was approximately 17% in 2006, a statistic that is consistent with the 13% to 24% found in other developed countries (such as the USA, France and Germany) (Cnattingius, 2004; PJ Laws & Hilder, 2008; Roske et al., 2008; Schneider & Schutz, 2008). Women with low socioeconomic status, lower education, unmarried and younger women were more likely to smoke during pregnancy (Chan & Sullivan, 2008; Isohanni, Oja, Moilanen, Koiranen, & Rantakallio, 1995; Paula Laws et al., 2006; Schneider & Schutz, 2008; Walsh, Redman, Brinsmead, & Fryer, 1997).

More broadly, studies looking at smoking cessation report cessation rates among pregnant women in developed countries varied from less than 20% (Connor & McIntyre, 1999) to more than 40% (Carmichael & Ahluwalia, 2000; Lindqvist & Aberg, 2001), due to varying definitions of cessation and differing data collection methods. Australian data also indicate that 34% to 55% of women who were smokers at the time they became pregnant quit smoking (Giglia, Binns, & Alfonso, 2006; Hotham, Ali, White, & Robinson, 2008; McDermott, Dobson, & Russell, 2004). While the majority of the quitters during pregnancy do so in the first trimester (Ford, Wild, Glen, Price, & Wilson, 1993), smoking prevalence generally remained relatively stable across the three trimesters of pregnancy (Hotham et al., 2008).

Furthermore, the results of this modelling showed that there was a 5% cost differential between a woman who smoked over 20 cigarettes per day and one who never-smoked (taking all other risk factors included in the analysis into account). Interestingly, there was still a cost differential of 1% between ex-smokers and never-smokers, providing evidence that smoking behaviours regardless of when they occurred have an impact on cost. The cost differential when grouping by smokers and non-smokers (including ex-smokers) was approximately 3%.

There are numerous international studies that consider the cost impacts of smoking during pregnancy, although to date no such studies have been conducted in Australia. The cost impact of smoking during pregnancy in the US was estimated to range from $US122 million to $US279 per smoker (Adams, Melvin, Raskind-Hood, Joski, & Galactionova, 2011) in 2004 dollars, but these estimates included infant costs. Additionally, estimated birth and first year costs for both mothers and infants attributed to smoking were $US1142 to $ US1358 per smoking woman over a

decade ago (Adams et al., 2002; Aligne & Stoddard, 1997; Miller, Villa, Hogue, & Sivapathasundaram, 2001). In the UK, the maternal health system cost from smoking has been estimated as GBP 8-64 million during the pregnancy period in 2005 (Godfrey, Pickett, Parrott, Mdege, & Eapen, 2008).

Interestingly, smoking status was not significant during the antenatal period (for both hospital and out-of-hospital costs). This is most likely due to the data in this period for hospital costs being quite sparse, as well as other more significant factors for out-of-hospital costs. However, the results showed that there was a clear cost impact during the delivery period and the impact varied depending on how much the woman smoked but was present regardless of when she smoked. Given these findings, it is logical to focus on the pregnancy period for smoking cessation as this is likely to influence the outcome during the delivery period. Alternatively, it would also make sense to consider smoking across the life course (say during the adolescent period) as early intervention and prevention of smoking is likely to reduce the prevalence of smoking during pregnancy (McDermott et al., 2004). As these are two large areas of research, the former is addressed in more detail here; however, the latter is beyond the scope of this thesis. Therefore, the next two sections consider the current national health policy for smoking during pregnancy and the existing research in this area.

7.2.1 Current national health policy

There have been numerous health campaigns to encourage women to stop smoking during pregnancy with details available on the Australian Government Department of Health's website for Maternal and Infant Health (Australian Government Department of Health). The most recent campaigns were as a result of $4.3 million in government funding over three years (2004-05 to 2007-08) to encourage doctors,

midwives and Indigenous health workers to advise pregnant women about the damage caused by smoking. This funding allowed for the establishment of "The National Advisory Group on Smoking and Pregnancy" initiative in 2006-07 to provide advice on the development and implementation of the Department of Health's Smoking and Pregnancy initiative including development and implementation of effective initiatives to assist pregnant women to stop smoking.

In addition to this campaign, the clinical practice guidelines for health professionals providing antenatal care in Australia (Australian Government Department of Health) provides information on the current practice in supporting women who smoke during pregnancy and these practices were based on high quality research from Lumley et al. (2009). In summary, the current health policy framework adopts the following approaches:

- Conduct an assessment of the smoking status of the woman and provide information on the risks to both the woman and the unborn baby.
- Offer women who smoke referrals for smoking cessation interventions such as cognitive behavioural therapy (CBT). Also offer women personalised advice at each antenatal visit.
- After these options are explored, nicotine replacement therapy (NRT) may be used.
- In any approach, consider reducing smoking if quitting is not possible and monitor and/or prevent relapses.
- Tailor support to specific population groups such as Aboriginal and Torres Strait Islander women and adolescent women.

- There is also advice on how to approach these women, particularly in terms of being non-judgmental and providing advice so that women can make informed choices.
- Monitoring these women and their progress is a key part of the current policy.

More details of these approaches and specific interventions are provided on the Australian Department of Health's website (Australian Government Department of Health). The research from the review that informed these guidelines and other reviews that have been conducted since that time are summarised in the next section.

7.2.2 Summary of the evidence

The most comprehensive research covering a vast breadth of studies in this area was conducted by the Cochrane reviews (Cahill, Hartmann-Boyce, & Perera, 2015; Chamberlain et al., 2013; Hajek et al., 2013; Lumley et al., 2009; Stead & Lancaster, 2012). The current guidelines were based on the Cochrane review by Lumley et al. (2009). This review showed that smoking cessation interventions improved smoking cessation rates by 6% and reduced rates of adverse births. Numerous interventions were studied in this review and it was found that CBT (including educational strategies and motivational interviewing) were similar in effect to interventions in general, however, incentive schemes (for example, vouchers) increased the effectiveness of interventions. The 'stages of change' theory of providing feedback to the mother did not improve cessation. While NRT was as effective as CBT, there was no clear evidence on the safety of its use during pregnancy. Other recent studies were consistent with the Cochrane review and found that telephone-based support combined with face-to-face sessions were beneficial (Dennis & Kingston, 2008);

providing information (for example, at ultrasound appointments) had a significant effect (Stotts et al., 2009) and smoking cessation may be influenced by concerns about weight gain (Berg, Park, Chang, & Rigotti, 2008). These interventions have all been shown to be cost-effective through economic analysis conducted within the Australian Government Department of Health with CBT being more cost-effective than NRT.

The latest Cochrane reviews in the area focus on psychosocial therapy (Chamberlain et al., 2013), pharmacotherapy (Stead & Lancaster, 2012) and relapse prevention interventions (Hajek et al., 2013) for smoking cessation during pregnancy and provided similar results to the Lumley et al. (2009) review. The pharmacological review (Stead & Lancaster, 2012) showed that NRT was the only pharmacotherapy for smoking cessation that had been tested in randomised controlled trials (RCTs) conducted in pregnancy and there was insufficient evidence to determine whether or not NRT was effective or safe when used to promote smoking cessation in pregnancy or to determine whether or not using NRT had positive or negative impacts on birth outcomes. Similarly, the relapse prevention intervention review (Hajek et al., 2013) found that there was insufficient evidence to support the use of any specific behavioural intervention to help smokers who had successfully quit for a short time to avoid relapse. Therefore, the psychosocial therapy review provided the most useful information and will be summarised below in terms of the key findings.

First, the types of interventions covered in the review are outlined Table 6.1:

Table 6.1: Psychosocial Interventions (Chamberlain et al., 2013)

Type of intervention	**Definition and examples**
Counselling	Women are provided with motivation to quit, through various channels such as motivational interviewing, CBT and psychotherapy.
Health education	Women are provided with information on the risks of smoking and advice to quit but not given further information on how to make the change.
Feedback	Women are provided with feedback with information about the fetal health status or measurement of by-products of tobacco smoking to the mother.
Incentive-based	Women receive a financial incentive, contingent on the smoking cessation (for example, vouchers).
Social support (peer and/or partner)	Any intervention that specifically includes social support
Other	Any other intervention including exercise and dissemination (that is, where both control group and intervention group receive the same information but disseminated in different ways).

The main findings from the review were counselling interventions demonstrated a significant effect on smoking cessation compared to usual care, and a borderline effect compared to less intensive interventions; however, a significant effect was only seen in subsets where counselling was provided in conjunction with other strategies (although it was unclear whether any type of counselling strategy was more effective than others). Incentive-based interventions had the largest effect size compared to a less intensive intervention and an alternative intervention (an

alternative intervention is one where the control group received different intervention components than the intervention group but of the same intensity). Note that this finding was also confirmed by a separate Cochrane review on just incentive-based interventions (Cahill et al., 2015). Feedback interventions demonstrated a significant effect only when compared to usual care and provided in conjunction with other strategies, such as counselling, but the effect was unclear when compared to a less intensive intervention. Social support interventions appeared effective when provided by peers, but the effect was unclear in a single trial of support provided by partners. Finally, women who received psychosocial interventions had an 18% reduction in premature births and infants born with low birth weight. There did not appear to be any adverse effects from the psychosocial interventions.

The conclusion of this review was that psychosocial interventions to support women to stop smoking in pregnancy can increase the proportion of women who stop smoking in late pregnancy, and reduce low birthweight and preterm births. Additionally, the review reported on cost-effectiveness studies which showed that these interventions were indeed cost-effective. Specific cost estimates of the interventions were also provided and most appeared to be well within the cost predictions of the models in this thesis (even after adjusting for inflation and exchange rates). However, a simple direct comparison such as this can only be used to broadly indicate potential cost-effectiveness in the Australian health system and a much more detailed cost-benefit analysis would need to be undertaken before any intervention is taken forward, as there are likely to be material differences between the health systems in these studies and the Australian health system.

Finally, the finding that incentives appear to boost cessation rates appears to have the most success in terms of improved outcomes according to the most recent research (Cahill et al., 2015). The two trials considered in this paper found that sustained success rates were achieved when substantial cash payments were awarded for abstinence. The authors commented that such an approach may only be feasible when independently-funded smoking cessation programs are already available and within a relatively affluent and educated population. Deposit-refund trials had lower rates of uptake but those who did sign up and contributed their own money may have achieved higher quit rates than reward-only participants. In conclusion, incentive schemes conducted among pregnant smokers improved the cessation rates both at the end of pregnancy and postnatally, but further research is required to consider the scale, loading and longevity of possible cash or voucher reward schedules within a variety of smoking populations.

7.2.3 Recommendations

What is clear from the findings above is that this is a complex area, with numerous factors that contribute to the tendency of a woman to stop smoking during pregnancy. Notwithstanding these complexities, there are also several benefits when the woman does quit, both in terms of the health outcomes for herself and her baby, but also in terms of cost-effectiveness and maternal health system cost reductions. There is evidence internationally that costs of interventions in this area are usually relatively low, so the effectiveness rates do not have to be particularly high for the programs to pay for themselves (Windsor et al., 1993). This is because the costs of service provision more than outweigh the savings from the reduced rates of adverse outcomes as a result of smoking during pregnancy.

Given the discussion in the previous two sections, the recommendations are categorised into long term and short term options to better address the complexities of the issues discussed thus far.

Long term recommendations

The effectiveness of the current health policy needs to be evaluated using more detailed data with a focus on the outcomes for women following the current treatment methods. This approach should include a comprehensive study on women who have smoked during pregnancy and the barriers they have faced to quit smoking. In particular, a better understanding of why women continue to smoke during pregnancy would be crucial in order to understand the issues with the current policy. This may be conducted by surveying these women and asking questions about how they felt about their current management options (as was done by (Chojenta, 2013) for women with postnatal depression). Following this, there should be a clearer understanding of the weaknesses with current health policy and policy may be targeted at these weaknesses. For example, if it is found that smoking women were not attending counselling appointments, a simple cost-effective way of encouraging them to attend is a text message reminder (with these implemented on an opt-out basis). Alternatively, an application for a smartphone or tablet could help track their progress if it was found that these women needed incentives and goals to maintain their program. With any intervention, a full economic cost-benefit analysis should be conducted in the Australian context. While the results of the models in this thesis provided important insights into cost differentials, this analysis needs to be supplemented with full ground-up costing of interventions and their benefits. Once this has been considered, policy may be formed that considers all the points above;

that is, the most recent research on effective interventions that will address the weaknesses in the current policies adopted, combined with a view of their cost implications. As with all policy, the effectiveness should be continually monitored in terms of the outcomes of the women who are involved in the programs.

There is a need for further research in a number of key areas. Firstly, further investigation on early intervention for smoking cessation of young women, particularly during the adolescent years, may reduce the prevalence of smoking during pregnancy (McDermott et al., 2004). In addition to this, there are likely to be numerous risk factors that contribute to a woman's tendency to smoke in the first place, a feature of the problem that should be addressed in any early intervention approach. Finally, further research on interventions such as the psychosocial approaches discussed here (both in Australia and internationally) and their effectiveness will provide important insights into other possible interventions. This would require a detailed and extensive literature review in this specific area and randomised control trials to better understand the effectiveness of these approaches.

Short term recommendations

One intervention showing clear evidence of successful outcomes was the incentives programs and accordingly deserves further exploration. While such programs may only be feasible when independently-funded smoking cessation programs are already available, they have been shown to be effective and with the cost estimates seen in the research (Cahill et al., 2015), they are likely to be cost-effective. However, a full economic cost-benefit analysis would be required in the Australian context before the interventions were to be implemented. This analysis would also require serious consideration of the negative ramifications of such an intervention, particularly in

terms of how other non-smoking pregnant women (Lynagh, Bonevski, Symonds, & Sanson-Fisher, 2011) and wider society would view the practice of paying women to quit smoking. Being able to communicate the complexities of these issues and the effectiveness of this intervention to non-smokers (especially pregnant women who are not smokers) would be fundamental to ensuring it was accepted by members of wider society.

7.3 Mental health

The results of the modelling showed that mental health factors were significant cost risk factors across most models, particularly for out-of-hospital costs. Intense anxiety was the only significant mental health factor in the hospital models and this was also only in the public antenatal model (which represented a small proportion of the total cost). Therefore, this discussion will focus on the out-of-hospital models only, as this is where the majority of the cost impacts for mental health lie.

Table 6.2 shows which out-of-hospital models the mental health factors were significant in, as well as the corresponding cost differentials for the mental health factors (note, they were not significant in any delivery models for out-of-hospital costs).

Table 6.2: Mental health factors by out-of-hospital model[13]

	Public		Private	
	Antenatal	Postnatal	Antenatal	Postnatal
Intense Anxiety	18%			
Postnatal depression		51%		23%
Anxiety		44%	20%	54%
Stress about own health		10%	7%	15%

The results showed that the cost differentials for each mental health factor were substantial; particularly postnatal depression for the public model, with women who had postnatal depression costing 51% more than women who did not have postnatal depression in the postnatal period. Furthermore, there was also a cumulative impact of these mental health conditions that should be considered here. As the models were multiplicative, the results showed that a woman from the public model who had all three mental health conditions in the postnatal period (that is, a woman who had postnatal depression, anxiety and was somewhat stressed about her own health) would cost 138% more than a woman in the public model who did not have any of these conditions. Note, that the stress about own health factor was categorised into six groups from "Not at all stressed" up to "Extremely stressed", and the cost differential for these two extreme categories were over 140%; however, there was only a very small proportion of women in the "Extremely stressed" category (approximately 1%). The results of the modelling also showed that the cost impacts of each of these conditions were more significant in the postnatal period compared to the antenatal period. Further, postnatal depression and anxiety have the highest cost

[13] The stress about own health cost differential is reported here as the difference between a woman who is not at all stressed and one who is somewhat stressed.

impacts across both the public and private postnatal models. Note also that the question regarding anxiety asked if the woman had received treatment for anxiety, so it was likely to have a cost implication based on the way it was asked (as opposed to a question which self-reported on whether the woman had experienced anxiety).

The significance of these cost risk factors was not a surprising finding, as it is well known that there was an association between poor psychological health and adverse birth outcomes (Alder et al., 2007; Hedegaard, 2002; Wisborg et al., 2008), and therefore the potential for significant cost ramifications as discussed in Section 2.3.4. The risk factors of perinatal mental health itself are varied and covered extensively in other literature (Chojenta, 2013); but key factors include family history of mental health disorders, lack of available support (including intimate partner violence), current or past history of abuse, low education/low socioeconomic status, perfectionist personality type and other stressful life events (Beydoun, Beydoun, Kaufman, Lo, & Zonderman, 2012; Boyce & Hickey, 2005; Chojenta, 2013; Chojenta, Loxton, & Lucke, 2012; Schmied et al., 2013). The two strongest predictors for depression and anxiety have been found to be previous history of depression (Chojenta, 2013) and poor partner relationship (Schmied et al., 2013).

In terms of the prevalence of mental health issues in the perinatal period, the proportion of women reporting depressive symptoms in the first year after birth was between 10% and 20%, and this has remained fairly stable over 25 years (Schmied et al., 2013). Postnatal depression was reported by 15.7% of mothers (aged up to 36 years) for any of their births who participate in the ALSWH (Chojenta, 2013). Furthermore, the findings from the Australian beyondblue National Postnatal Depression Program which was an initiative that ran from 2001-2005 suggested that

15.5% of women were affected by postnatal depression, but these results vary by state and in some states also varied by whether they used private or public health services (for example, it did for Western Australia but not for the Australian Capital Territory, where income and education are significantly higher than for other states for both groups) (AE Buist et al., 2008).

All of these reported rates are consistent but mainly relate to postnatal depression and, critically, do not include anxiety disorders. Unfortunately, anxiety disorders during pregnancy are often overlooked and are therefore less understood. Consequently, there was less evidence about anxiety in the perinatal period (Schmied et al., 2013). Schmied et al. (2013) found evidence that 7.3% of women reported experiencing intense anxiety or panic attacks (which are consistent with the definitions used in this research) either occasionally or often in pregnancy 15.7% in the first 3 months postpartum, 10.9% at 6 months and 8.5% at 9 months postpartum. Further, 10.7% of women were anxious at the first antenatal clinic visit and 9.1% at 6 months after birth.

The out-of-hospital study in the current research also considered the development of these conditions over the postnatal period. For private costs, stress about own health was significant within two months of delivery, but anxiety and postnatal depression took a little longer to develop (at 4 months and 6 months, respectively) in terms of their significance on cost. Once these conditions became significant, they persisted up until the 12-month mark, when the postnatal period ends for this study. For public costs, stress about own health develops a little later, at 4 months, and postnatal depression and anxiety take a little longer again, this time at 6 months and 12 months, respectively. Both stress about own health and postnatal depression

remained significant until the end of the postnatal period. In terms of the results of other studies, they tend to focus on the first year following birth and were inconclusive as to prevalence during this first year, largely due to the methods by which data were collected at various points during the postnatal period (Schmied et al., 2013). However, perhaps one of the most interesting findings in this area in terms of when women were most likely to experience depressive symptoms comes from two studies which showed that the first year following a birth was *not* the time most women were most likely to experience depressive symptoms (Loxton & Lucke, 2009; Najman, Andersen, Bor, O'Callaghan, & Williams, 2000). For example, one study found that depressive episodes were neither long-lasting nor severe when they occurred in the six months after birth; however, 25% of women experienced an increase in symptoms on self-report from the six-month follow-up to the five-year follow-up (Najman et al., 2000). This is confirmed by an ALSWH study which found that a woman's mood was generally more positive in the first 6-12 months after birth than in subsequent years and that women, particularly those with babies under 12 months of age in ALSWH, had higher self-rated physical and mental health than both other mothers and women without children (Loxton & Lucke, 2009).

In terms of analysing the health system cost of mental health issues during the perinatal period, Deloitte Access Economics were commissioned by Post and Antenatal Depression Association (PANDA) to study the financial costs of perinatal depression in Australia. They estimated direct health costs of $60.68M in 2012, of which $29.60M related to costs incurred by the government (Deloitte Access Economics, 2012). The latter cost equated to $651.61 per woman who had perinatal depression. Surprisingly, the majority of the costs reported in their study related to hospital costs, and primary care represented a much smaller proportion of the total

direct health costs. This contrasts with the results of this thesis, which found that depression was more significant for primary care costs (that is, in the out-of-hospital models) compared to hospital costs. This distinction is likely because of the differences in the data gathering mechanisms and analysis methodology used, and as the antenatal and postnatal hospital models lacked sufficient data to form any definitive conclusions on significant cost risk factors. Furthermore, this thesis considers a multivariate analysis, which takes into account the effects of multiple other covariates that may be driving costs, and it is unclear whether the Deloitte Access Economics/PANDA study approached the cost differentials within an appropriately multivariate framework. However, regardless of this difference, what is clear from the PANDA report is that perinatal depression has major cost implications in Australia.

Given the limited research in the area of perinatal anxiety, the following two sections focus on health policy for perinatal depression; however, given that these conditions are so closely related, much of the discussion is also relevant for anxiety management too.

7.3.1 Current health policy

There are several important developments in the area of perinatal depression in terms of research and policy in the last ten years. The major policy developments have been the establishment of the National Action Plan for Perinatal Mental Health (beyondblue: the national depression initiative and Perinatal Mental Health Consortium, 2008), the implementation of the National Perinatal Depression Initiative (NPDI) (Australian Government Department of Health and Ageing) and the implementation of the NHMRC-endorsed beyondblue Clinical Practice

Guidelines for Depression and Related Disorders in the Perinatal Period (Austin & Highet, 2011). The goals of the NPDI were to improve the prevention and early detection of antenatal and postnatal depression, and to provide better care, support and treatment for expectant and new mothers experiencing perinatal depression. Unfortunately, the funding for this initiative has recently concluded; however, it is worthwhile considering the key ideas that this initiative encompassed. The initiative was targeted at identifying women most at risk of perinatal mental illness through national guidelines for screening perinatal depression, which included routine and universal screening for perinatal depression in the antenatal period and follow up support and care for women assessed as being at risk. In addition to this, workforce training and development for health professionals and further research and data collection were also priorities.

Further, the overall approach to care in the beyondblue Clinical Practice Guidelines is consistent with these ideas and involves routine assessment of psychosocial factors and current symptoms of depression or anxiety as part of the broader care of women in the perinatal period. This assessment is not intended to predict depression or to replace clinical diagnosis; rather, it is to be used alongside it. These guidelines have two key principles on which the previous system did not necessarily focus – that is, follow-up care for women at risk (for example, women who appear to have symptoms of anxiety or depression), and a better-defined pathway to care. Every woman who has had follow-up care is given a pathway to care, or "map", by which she and her family can access the most appropriate psychosocial care and support. There are many factors considered in defining the pathway to care, including the severity of the symptoms and the woman's preferences and specific circumstances, so that a tailored, individual approach is achieved. Care is also based on

collaborative decision-making about treatment options, a strategy for relapse prevention, continuing monitoring and assertive follow-up. The principles underlying effective provision of appropriate care included utilising services from health professional with appropriate skills and training with these professionals referring to other professionals or services where required, continuity of care or carer and a multidisciplinary team approach whereby a range of professionals are available to provide services.

In terms of clinical care and treatment, according to the current GP clinical guidelines (The Royal Australian College of General Practitioners) there are effectively two forms of treatment: one is through psychological methods (such as counselling) and the other is through medication, which has risks during pregnancy and lactation. This guideline is consistent with Chojenta's findings (2013) (from a qualitative sub-study) that only two different forms of treatment were described by women who experienced postnatal depression; that is, antidepressants and counselling. Those who had received prescriptions for antidepressants described long-term use of those medications, with little medical follow-up. While participants described improved mood after taking medications, they also perceived that long-term use was the only solution to their mood disorder. This research was conducted prior to the release of the beyondblue Clinical Practice Guidelines, in which follow-up is now a key principle. For the counselling element, there was mixed feedback on its effectiveness. Several participants described dissatisfaction with one counsellor, and a lack of perseverance either with the same counsellor or another after one unsatisfactory session. These findings indicated that patients required greater understanding of the options available to them regarding counselling and treatment options in order to optimise treatment success, which is also considered in more

detail in the beyondblue Clinical Practice Guidelines in terms of collaborative care that is more patient-centred.

The current clinical guidelines also emphasise screening all women in the perinatal period – as there is still evidence to suggest there is a stigma associated with depression as well as strong disincentives for women to acknowledge that they might be at risk or need help (Bilszta, Ericksen, A, & Milgrom, 2010), so screening all women will not rely on these women to seek help of their own accord. Buist et al. (2002) also found that adequate screening for postnatal depression symptoms was necessary to facilitate early intervention. Although awareness campaigns help, some women still struggle to recognise that they might be depressed, particularly when the pregnancy has been planned and the baby is wanted and loved. The current screening methods (through the Edinburgh Postnatal Depression Scale (Cox, Holden, & Sagovsky, 1987)) does not necessarily mean that the woman has a psychiatric illness, but it does raise the possibility that she will nevertheless benefit from help.

In terms of evaluation of effectiveness of the current screening programs, in particular the NPDI, there have been a number of relevant studies that should be considered. Firstly, Reilly et al. (2013) found that 66.8% of women reported being asked about their current emotional health in the antenatal period, increasing to 75.6% of women in the postnatal period but that rate decreased markedly for reported assessment of mental health history (ALSWH data were used in this study). The authors also found that women who gave birth in public hospitals were more likely to be assessed in the antenatal period compared to women who gave birth in the private sector showing there was a need to increase assessments or potentially even awareness in the private system. Following this study, a specific evaluation of

the impact of the NPDI on access to Medicare services for women at risk of perinatal mental illness was conducted (Chambers et al., 2015), and found that in the two years following its introduction the initiative had increased access to Medicare funded mental health services in particular groups of women. However, an overall increase across all groups did not reach statistical significance. In other words, these findings showed that while the NPDI had resulted in more women at risk of perinatal mental health illness accessing more mental health services, it was inconclusive in terms of whether the initiative had lead to better outcomes as the results were not statistically significant. This study also recommended further research to assess the impact of the NPDI on women during childbearing years, including access to tertiary care, the cost-effectiveness of the initiative and mental health outcomes. The authors also comment that new initiatives in the area incorporate a planned strategic approach to evaluation, which includes sufficient follow-up to assess the impact of public health strategies. It must be noted, however, that the NPDI is no longer mandatory following the withdrawal of funding for it.

7.3.2 Summary of the evidence

The evidence from past studies strongly agrees that “prevention” of postnatal depression can be promoted by antenatal screening of risk factors such as current mood state (Austin, 2004; Boyce & Hickey, 2005; Milgrom, Schembri, Ericksen, Ross, & Gemmill, 2011) or by early postpartum screening (Chen et al., 2011). The screening approach under the current guidelines is based largely on the mood state at the time of screening. However, a comprehensive study on the prevalence, antecedents and perceptions of efficacy of treatments of postnatal depression in Australia by Chojenta (2013), using ALSWH data, finds that there are earlier opportunities to intervene, as detecting early mental health risk, in particular,

provides an opportunity to prevent recurrence of mental health dysfunction. This finding is consistent with the finding that the most important predictor of postnatal depression is previous mental health disorders (Boyce & Hickey, 2005; Chojenta, 2013; Chojenta et al., 2012; Schmied et al., 2013). Chojenta (2013) recommended all women of childbearing age, or even prior to childbearing age, who have experienced depression should be considered to be at high risk of postnatal depression, and therefore additional support and preventative strategies should be targeted at this group. Chojenta's study showed that there were also likely to be significant cost benefits, as a more proactive early intervention approach to perinatal mental health management is likely to avoid significant costs of treatment at later stages when the condition has worsened. This possibility is further evidenced by the results of this thesis which showed that postnatal depression and anxiety were not significant cost risk factors in the first 4 months following the birth of the baby but that they became significant around this time (for both private and public) and thereafter persisted until the end of the first year. These women may have been at risk earlier but go undetected through the current screening approaches, and therefore the cost ramifications were only seen later in the postnatal period. In addition, this research showed that the cost differentials persisted until at least the end of the first postnatal year (when this thesis study ends), so it is possible that they may even continue beyond this time. It would be worthwhile considering a longer postnatal period for further study as previous research (Loxton & Lucke, 2009; Najman et al., 2000) has also suggested that problems with mental (and physical) health tended to be worse in later postnatal years.

Chojenta (2013) also described the advantages and disadvantages of rolling out universal national screening protocols. First, she suggested that there may be an

overestimation of cases involving women who were screened for current mood and scoring highly, perceiving this as a clinical diagnosis of postnatal depression. The diagnosis of the condition requires further detailed evaluation following initial screening by the practitioner under current guidelines. However, the advantage is that the screening is likely to detect cases that would otherwise go undetected. The clinical guidelines recommend psychosocial risk assessment be combined with current mood screening in order to most accurately detect those women at greatest risk of postnatal depression. Furthermore, Chojenta (2013) found a number of additional risk factors for postnatal depression that may be used in the screening process. For example, psychosocial risk factors give the practitioner opportunities to intervene at an earlier time, or indeed to identify those patients at higher risk of developing perinatal mood disorders in the future. In addition Chojenta identified factors such as infertility, reproductive health history and physical health conditions that could be incorporated into screening protocols. Furthermore, breastfeeding problems and sleep disturbance may be indicators of risk which were also common among the non-depressed population of new mothers, but the cumulative impact of mental health disturbance with other factors such as infant feeding may pose an additional threat to women already at greater risk of postnatal depression. Again, incorporating these and similar factors into the screening guidelines is likely to reduce the costs of treating these women in the future.

Other areas which Chojenta (2013) identified as critical in treating women with suspected postnatal depression were those who had tried health services for their problems but then expressed dissatisfaction with these services. Chojenta (2013) suggested these women were less likely to attend follow-up appointments or to develop rapport with clinicians due to this past dissatisfaction, and were therefore

inherently harder to support. In some sense, these are women that "fall through the cracks" of the system because they perceive the system to have failed them. They are also more difficult to reach as they are not using the health services, and potentially such cases have major cost implications as they are not managing their mental health disorders in their early stages. This situation then leaves these women at future risk of more serious mental health conditions that require more expensive treatment.

In addressing perinatal mental health management and prevention, it is also worth exploring wider mental health prevention strategies and there are two areas of significance that should be discussed as they currently form the basis of mental health prevention strategies in Australia. The first is the Headspace initiative which is targeted at young people and the second is the recent government reforms in this area and each will be discussed in turn.

Patrick McGorry's Headspace initiative (2012) is a recent example of a program based on the premise of early intervention and prevention of mental health conditions for young people via "one stop shop" type establishments which aim to holistically treat not only the symptoms of mental health conditions but also the recent provocative agents that may impact on the severity of symptoms (Headspace, 2012). This strategy is consistent with the discussion above in terms of a proactive early intervention approach to care. Chojenta (2013) suggested that such strategies in young women could lead to a "reduction in the prevalence of postnatal depression and break the cumulative impact of mental health dysfunction for women across the life course". As with all the strategies discussed above, the focus on early intervention is highly likely to reduce future health system costs of perinatal mental health.

The recent reforms to this sector are likely to significantly change the way mental health is treated in this country (ABC News, 2015). The reforms focus on individual, patient-centred care, as opposed to the current approach which is based on a "one-size-fits-all" model. The new guidelines have been referred to as a "stepped care" model which gives people various levels of mental health care depending on their needs. The type of care could range from small temporary interventions (such as online help) for mild risks, to complex individualised care packages for more severe cases. As part of this policy, services have also been integrated by combining numerous existing government supported telephone services into one hotline and digital gateway. The digital gateway will offer services online which include e-therapies, help lines and self-help programs. While these reforms do not specifically address perinatal mental health prevention, they are a step in the right direction in terms of patient-centred care and integrated service provision, and will also provide services for young people (alongside Headspace), which is important in terms of the early intervention benefits discussed earlier. The evaluation of these new initiatives will be imperative to understanding whether they improve the outcomes of individuals at risk and may provide evidence of alternative approaches that could be used within perinatal mental health prevention as well.

7.3.3 Recommendations

There are numerous areas in which the current health policy in this area has weaknesses, and this thesis shows that these weaknesses are likely to be having significant health system cost impacts. The current weaknesses are largely due to inadequate screening methods and/or health services for women at risk. Recommendations to address these weaknesses are discussed under three categories: improved screening, early intervention and increased funding.

Improved screening

There are two aspects to the inadequacy of the current screening approaches. The first is that the screening is not universal, and the second is that the screening methods themselves can be improved. It is strongly recommended that universal antenatal and postnatal screening for mental health risk factors are put in place for all women in Australia. The results of this study showed that mental health factors were significant drivers of cost in both of these sub-periods, and therefore they should be addressed at both stages. In addition to this, further research is required on addressing issues related to anxiety disorders, in particularly, screening methods for anxiety during pregnancy as this was also a significant cost risk factor. This particular area is largely overlooked in the current literature (Schmied et al., 2013), and therefore further research is required to understand the best way of addressing it.

Currently there is no funding supporting these approaches, and previous and current research suggest this is critical to the prevention and management of these mental health conditions (Austin, 2004; Boyce & Hickey, 2005; Chambers et al., 2015; Chen et al., 2011; Milgrom et al., 2011). Chojenta (2013) also suggests screening strategies are cost-effective as they are relatively easy to initiate as routine training for all clinicians who have contact with pregnant and postnatal women.

It is also strongly recommended to incorporate the findings from Chojenta's (2013) study into current screening methods. The additional risk factors identified include a history of depression, infertility, reproductive health history, physical health conditions, breastfeeding problems and sleep disturbances.

Early intervention

Past research has shown that early intervention is key to successful future outcomes as previous mental health disorders are a major indicator of future mental health disorders (Boyce & Hickey, 2005; Chojenta, 2013; Chojenta et al., 2012; Headspace, 2012; Schmied et al., 2013). Chojenta (2013) recommends that all women of childbearing age that have a history of depression are at high risk and resources should be targeted to them. This recommendation also aligns with broader mental health strategies such as Headspace. The improvements to screening discussed above will also ensure that mental health disturbances will tend to be detected earlier. The research in this thesis, critically, also showed that while mental health conditions had significant cost impacts later in the postnatal period, once they were significant they persisted at least until one year following the birth of the baby. This lag and then persistence may be due to lack of early intervention before these conditions become more serious and needing expensive treatment and/or care. Also, as noted under "Improved Screening", early intervention approaches should also specifically consider anxiety disorders as this research showed this is a significant cost risk factor and currently largely overlooked (Schmied et al., 2013).

Increased funding

Increased funding is required to improve the quality of health services (particularly counselling services) to mitigate the potential for women to fall through the cracks of the current system due to dissatisfaction with their health services. These women are currently not even taking up the services being offered and policy should be addressed at the poor take-up rate. While this may seem to contradict the results of the current study, which showed that women with mental health disorders were using

more services, it may constitute evidence that the costs observed in this thesis were actually understated, as there may be a group of women who need these services but are dropping out of the system because they are unhappy with the services they receive. These women may also be returning to the system at later stages and seeking treatment when their conditions are more severe and, as discussed above, early intervention and then following a specific, tailored pathway of care is fundamental to better health outcomes and ultimately cost savings.

Finally, despite the results of this study providing strong evidence that health initiatives regarding mental health are likely to be cost-effective and worth exploring further, a full cost-benefit analysis should be conducted before any initiative is taken forward. The costs of national universal screening and improving health services in this area may be high, but this must be considered alongside the upside of better health outcomes, and a cost-benefit analysis for these initiatives is also recommended. The results of the Deloitte Access Economic review (2012) showed that even these costs may be well within the cost differentials seen there.

7.4 Summary of policy initiatives

There have been a number of areas where the results of this thesis have showed that changes in health policy could produce better outcomes for women in a cost-effective manner. The two areas studied in more detail include smoking and mental health, and the key policy initiatives recommended from each of these areas are summarised below.

For smoking, there was evidence to show that offering incentives for smokers to quit during pregnancy reduced the prevalence of smoking during this time. This was the

only intervention where strong evidence already existed from randomised control trials (Cahill et al., 2015). However, there were also a number of other interventions that should be considered (for example, psychosocial interventions), but these require further investigation to provide a solid evidence base as to their effectiveness.

Numerous initiatives were considered for mental health management during pregnancy. They focussed on universal, routine screening with improved methods to capture the key risk factors, early intervention in high risk young women to reduce the prevalence of mental health illness during pregnancy and finally increased funding to treat the more complex cases that are currently being untreated for various reasons. There has already been significant research in this area by Chojenta (2013), and the evidence base is strong for many of these initiatives to be taken forward. The cost differentials found in this study showed that these initiatives are likely to be cost-effective.

As discussed in each section, before any initiative or intervention is implemented, a full cost-benefit analysis should be conducted. Also, a strategic plan for evaluation of the initiative (including data collection) as well as methods for continual monitoring of the maternal outcomes should be considered prior to service delivery.

Finally, all of these recommendations need to be considered in light of the evidence from which they are formed. Therefore, the next two sections provide more detail on the strengths and limitations of this thesis. Following this, areas for further research from the thesis are summarised.

7.5 Strengths

There are several strengths of this thesis. First, it is the first of its kind in Australia and therefore important to informing evidenced driven health policy. Second, the research utilises a representative longitudinal dataset to evaluate the cost differentials and cost risk factors with a breadth of key covariates (such as demographic, birth and health factors) that are not available in many other sources of data (even administrative data). Third, the quality of the data is enhanced by the process of linkage to various administrative datasets that offer important insights into health system costs. The combination of these data sources makes this project unique in terms of understanding the cost differentials and their drivers. The longitudinal nature of the data also allows for an in-depth analysis of three sub-periods in the perinatal period (antenatal, delivery and postnatal), a feature that few studies have covered in detail. Fourth, having access to both out-of-hospital and hospital cost data provides coverage of the major components of the health system in this area. Finally, the ability to link important events together – for example, the prevalence of mental health following the birth of a baby and subsequent cost implications – is another critical benefit of the approach.

In addition, this project uses sophisticated statistical and actuarial techniques to model the cost risk factors and these factors can then be used to provide advice on policy that can target women who are most at risk. This theme is consistent with the principle of evidence-informed policy. While further cost-benefit analysis is required for any policy recommendation, the results of the costing studies in this thesis provide a sound basis and informed starting point for which that analysis can be taken forward.

Finally, and related to the point above, this study is also the first time actuarial techniques have been applied to maternal health system costs, and thus this work is an important example of how actuarial skills are transferrable from traditional areas of actuarial work to non-traditional areas. Many key principles from general insurance (which is a traditional area of actuarial work) have been utilised in this study, namely: the use of exposure as a measure of risk; the use of numerous risk factors to explain cost drivers; inflationary considerations of cost over different time periods; segmentation of costs into different sub-periods; segmentation of costs into small and large; and, finally, separate analysis of frequency and severity of costs. These are all aspects that typically be addressed in an extensive general insurance pricing exercise and this approach would be familiar to practitioners in the area. This study shows that these types of actuarial techniques which have been used in general insurance for decades (Brockman & Wright, 1992; Hart et al., 2007) are successfully transferrable to other disciplines – such knowledge translation offers insights that have hitherto been unavailable in research on maternal health system costs. In addition to this important contribution to actuarial work, the use of the results to inform policy using a substantive evidence base with a focus on risks (which is the crux of this research) is a current area of focus of the Actuaries Institute (Actuaries Institute, 2015). Public policy is an area in which actuaries have been increasingly involved, and this research is an example of how actuaries can take advantage of their multidisciplinary skill-set in an area that has significant health policy implications. This research brings together elements of numerous disciplines and applies a holistic approach to provide important insights into health policy - this is a critical advantage of the actuarial approach.

7.6 Limitations

The major limitation compared to other similar studies is the relative lack of data in some periods (for example, the postnatal and antenatal hospital costing periods), especially when compared to the studies that consider data collected nationally on all births and corresponding hospital records (Gilbert et al., 2003; Ringborg et al., 2006). However, these other studies are unable to capture and model the effects of key covariates in the detail studied here as data is not typically collected at the national level (for example, the data collected on smoking status is typically not reliable in administrative datasets such as the APDC).

Related to the point above, there is also a significant gap in the data available for antenatal care provided in public hospitals through outpatient departments that are not billed to Medicare. While this will underestimate the actual costs incurred in this period, it may also introduce a selection issue if women who use these services are different to those who use Medicare claimable services. However, the focus of this thesis is to look at the Medicare costs and the data analysed does this. Unfortunately there is no data currently collected to analyse outpatient costs.

The other limitation with the dataset utilised in this project is the reliability of the self-report questions such as the adverse births and postnatal depression items. However, validation of the self-report measure of adverse births (only used for out-of-hospital costing) has been conducted and found to be reliable (Gresham et al., 2015). On the other hand, for other items such as postnatal depression such validation is harder to conduct, but they have been broadly compared to previous research where possible, and they fall within expected ranges, lending strength to the

validity of self-report items used (Australian Longitudinal Survey for Women's Health, 2014; Chojenta, 2013).

The use of survey data also gives rise to a number of limitations. Firstly, as the ALSWH survey is longitudinal in nature, there were issues with attrition over time and this was described in Section 3.1.1. Further to this, even when surveys were returned, there may be missing records due to questions not being answered. The data linkages also presented a number of data limitations; namely the possibility of a bias inherent to the MBS linkage due to women opting out of consent for linkage (see Section 3.4.2.1), but also in terms of mismatches in time frames across various datasets. There were also an immaterial number of erroneous records identified and removed. Full details of the data reconciliations and reasons for removing records are provided in Section 3.4.2.3.

Lastly, the constraint faced here with the two distinct data sources (for hospital and out-of-hospital costing) which could not be linked together prevented the analysis of these costs together. Ideally, the data linkage would have allowed hospital costs to be linked with the out-of-hospital costs (that is, Medicare data) for each individual in the study. This was not possible for these studies but it would allow for interesting analysis on how these two types of costs interact together on an individual basis. For example, the linkage of these data would allow researchers to study whether out-of-hospital and hospital costs are correlated with each other or independent of one another.

7.7 Further research

There have been a number of areas identified in this thesis that warrant further analysis. Most of the areas described below require a more detailed analysis of these data and in some cases different datasets would be required to understand the issues in more depth.

Reasons for caesarean delivery: Mode of delivery was a significant driver of the hospital costs, with caesarean deliveries costing significantly more than vaginal deliveries. Furthermore, the evidence showed there were substantial increases in the rates of caesarean deliveries over time and a need for better data to understand the underlying drivers of these increases (Australian Institute of Health and Welfare, 2014a) and more importantly whether they are leading to improved outcomes.

ART and IVF patients: A better understanding of ART and IVF in particular is warranted, given the major impacts they have on the costs incurred in this area. A more complete understanding of the complexities of the care of ART patients and how such factors drive these results would help in understanding whether they are indeed necessary costs and improving the outcomes of these women. As there is still a low prevalence of ART in Australia, a larger dataset would be required to complete such an analysis.

Specialist and GP use: A better understanding of the model of care during pregnancy is needed, particularly the interactions between specialist and GP care and the impact this can have on the maternal health system cost. More importantly, the impact these different types of care have on infant and maternal outcomes needs strong consideration. Both specialist and GP use were significant factors in the out-

of-hospital models, as was model of care for private obstetrician in some hospital models.

Private health insurance: It was clear throughout this thesis that the mixed public and private maternal health system had an important role in the drivers of the costs. It was also found that adverse births was a significant cost risk factor for public patients but not private patients (in the hospital costing study). In order to understand these issues better, further research on the demographics and health characteristics of those that take-up private health insurance in this area would be useful. In particular, a better understanding of how patients with private health insurance differ from those without would be useful to provide policy around the mixed health care system.

Interactions between hospital and out-of-hospital costs: A study on the links between hospital and out-of-hospital costs would be useful to track total costs of women through their complete perinatal care pathway. For example, this type of analysis would be able to answer questions such as whether women who are high cost in one phase are also high cost in another phase. This study would require a dataset that links these two costs together.

Policy initiatives: There were numerous areas recommended for further research for each of the two areas discussed with regard to health policy and the details of this required research is outlined in each of the recommendations sections in this chapter. Further, a full cost-benefit analysis and a planned strategic approach to evaluation, which includes sufficient monitoring of the initiative or intervention, should be considered before any intervention is adopted.

7.8 Conclusion

This is the first study of its kind in Australia that addresses the question of whether women who experience adverse birth outcomes have higher maternal health system costs than women who do not. The study showed that this is indeed the case with mean cost differentials of 23% and 27% for hospital and out-of-hospital costs, respectively, figures that provide strong evidence as to the depth of this problem in Australia.

However, understanding the drivers of cost differentials is the key to identifying ways to ensure that cost differentials are reduced and also to help improve the health outcomes for the women involved. The multivariate modelling framework showed that there were numerous factors that were statistically significant to this cost, and that they differed between hospital and out-of-hospital cost models, and across the perinatal periods studied. Costs also differed between private and public models. The key factors identified across most models included: specialist use, GP use, mode of delivery, IVF, smoking status, diabetes, mental health factors and adverse births. Many of these factors warrant further research before appropriate policy can be proposed and evaluated, but smoking and mental factors were considered further in detail in this chapter as they themselves are well-known risk factors of adverse births.

The findings from the policy discussion showed that there are some specific areas that can be isolated for new health policy that are likely to be cost-effective and produce better outcomes for women. The discussion considered the results of this research but also new and emerging research under the philosophy of evidence-informed policy. The recommended initiatives included smoking cessation

interventions such as incentive schemes for women who smoke during pregnancy. Numerous mental health initiatives were considered, notably a call for a national universal mental health screening protocol for antenatal and postnatal periods in conjunction with improved screening methods and health services that focus on holistic, proactive early intervention so that mental health problems are detected and treated early. Such a policy is likely to reduce the severity and recurrence of mental health impacts in the future, thereby reducing the health system cost implications. While these recommendations are likely to require increased funding in some areas, the cost differentials found in this study suggest they are worth exploring and analysing further. Not only are the initiatives likely to be cost-effective, but more importantly, they are likely to improve the health outcomes for the women who are most at risk of experiencing these adverse conditions.

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APPENDIX

Appendix A

Data dictionary for administrative datasets (formats in CD)

NAME	LABEL	SOURCE
ab	Adverse birth - derived variable	PDC
pain_com2	Analgesia for delivery - Combined spinal-epidural	PDC
pain_epi2	Analgesia for delivery - Epidural or caudal	PDC
pain_ga2	Analgesia for delivery - General anaesthetic	PDC
pain_loc2	Analgesia for delivery - Local to perineum	PDC
pain_nil2	Analgesia for delivery - None	PDC
pain_oth2	Analgesia for delivery - Other	PDC
pain_pud2	Analgesia for delivery - Pudendal	PDC
pain_spi2	Analgesia for delivery - Spinal anaesthetic	PDC
DELIVERY	Type of delivery	PDC
EPIDURAL	Epidural block?	PDC
INFECTN	Major puerperal infection?	PDC
OAPHCU	APH (cause unknown)?	PDC
OAPHPA	APH (due to placenta abruption)?	PDC
OAPHPP	APH (due to placenta praevia)?	PDC
OCS	Cervical suture?	PDC
OPROM	Prelabour rupture of membranes >24hrs?	PDC
OTMC	Threatened premature labour?	PDC
PRESENT	Presentation	PDC

admbdef	Admitted to special care nursery (SCN) or neonatal intensive care unit (NICU) due to birth defect	PDC
admitnic	Admitted to NICU	PDC
admitscn	Admitted to special care nursery (SCN)	PDC
ahs05hos	Health Area (2005) of hospital	PDC
anc	Was antenatal care received?	PDC
ancare	Wks pregnant 1st antenatal visit	PDC
ancare2011	Duration of pregnancy at first comprehensive booking or assessment by a clinician	PDC
ancarenum	Number of visits prior to birth - excluding separate day assessment and antenatal admissions	PDC
apgar1	Apgar score (1 min.)	PDC
apgar5	Apgar score (5 min.)	PDC
aph	Antepartum haemorrhage (any cause)?	PDC
arhshos	Health Area (1996) of hospital	PDC
arm	Induction/augmentation by ARM	PDC
bdatedth	Baby's date of death	PDC
bdisch	Baby's discharge status	PDC
bdisch06	Baby's discharge status	PDC
bdisdate	Baby's discharge/transfer date	PDC
bdob	Baby's date of birth	PDC
bresus2011	Resuscitation of baby	PDC
bresusci	Resuscitation of baby	PDC
bsex	Baby's sex	PDC
btrans	Transfered to hospital	PDC
bweight	Birth weight (grams)	PDC

contcarer	Was mother in a midwifery continuity of carer program for antenatal, birth and postnatal care?	PDC
csbirth	Last birth by caesarean section?	PDC
cstotal	Number of previous caesareans	PDC
cswhy	Main indication for caesarean section	PDC
cswhy06	Main indication for caesarean section	PDC
deliv98	Delivery	PDC
deliv2011	Type of birth	PDC
dthtype	Death type	PDC
episiot	Episiotomy?	PDC
gestage	Estimated gestational age (wks)	PDC
hoscode	Hospital	PDC
indaugot	Induction/augmentation by other method	PDC
inducwhy	Main indication for induction	PDC
labons	Labour onset	PDC
level	Hospital Obstetric Level	PDC
lhd_hosp	Local Health District of hospital	PDC
mdiab	Maternal diabetes mellitus?	PDC
mdisch	Mother's discharge status	PDC
mhyper	Maternal hypertension?	PDC
mod_an_gp	Model of care-antenatal - general practioner	PDC
mod_an_h	Model of care-antenatal - hospital based medical	PDC
mod_an_im	Model of care-antenatal - independent midwife	PDC

mod_an_m	Model of care-antenatal - hospital based midwife	PDC
mod_an_na	Model of care-antenatal - not applicable	PDC
mod_an_ob	Model of care-antenatal - private obstetrician	PDC
mod_b_gp	Model of care-birth - general practioner	PDC
mod_b_h	Model of care-birth - hospital based medical	PDC
mod_b_im	Model of care-birth - independent midwife	PDC
mod_b_m	Model of care-birth - hospital based midwife	PDC
mod_b_na	Model of care-birth - not applicable	PDC
mod_b_ob	Model of care-birth - private obstetrician	PDC
mtrans	Hospital for receiving transfered mother	PDC
mumAge	Mother's age	PDC
nic_bdef	Birth defect the main reason if admitted to NICU	PDC
oamn	Amniocentesis (<20 wks)?	PDC
odiab	Gestational diabetes?	PDC
ohyp_np	Gestational hypertension	PDC
ohyp_p	Preeclampsia	PDC
ohyper	Pre-eclampsia	PDC
oxytocic	Induction/augmentation by oxytocics	PDC
placebth	Baby's place of birth	PDC
plural	Plurality of birth	PDC

plurnum	Birth order	PDC
ppn_baby	Baby Project person number	PDC
ppn_mum	Mum Project person number	PDC
pregnum	Number of previous pregnancies	PDC
presen06	Presentation	PDC
presen98	Presentation	PDC
prevpreg	Previous pregnancy >20 wks?	PDC
project_recid	Project record ID - PDC	PDC
prostagl	Induction/augmentation by PGs	PDC
repair	Surgical repair of vagina or perineum	PDC
scn_nic	Admitted to special care nursery or neonatal intensive care unit	PDC
scn_obs	Admitted to SCN for observation only	PDC
Smoke	Any smoking during pregnancy?	PDC
smoke1st	Any smoking during the first half of pregnancy?	PDC
smoke1stgp	Number of cigarettes smoked per day in the first half of pregnancy	PDC
smoke2nd	Any smoking during the second half of pregnancy?	PDC
smoke2ndgp	Number of cigarettes smoked per day in the second half of pregnancy	PDC
Smokeqty	Cigarettes per day - 2nd half	PDC
Xrank	Confinement based on first baby	PDC
PPN_baby	Baby Project person number	APDC
PPN_mum	Mum Project person number	APDC
Adm_date	Admission date	APDC
acute_flag	acute_flag	APDC
ahs_of_facility	ahs_of_facility	APDC

ar_drg	an_drg	APDC
ar_drg_version	an_drg_version	APDC
area_identifier	area_identifier	APDC
block_numP	block_numP	APDC
clinical_codeset	clinical_codeset	APDC
days_in_psych_unit	days_in_psych_unit	APDC
diagnosis_code1	diagnosis_code1	APDC
diagnosis_code2	diagnosis_code2	APDC
diagnosis_code3	diagnosis_code3	APDC
diagnosis_code4	diagnosis_code4	APDC
diagnosis_code5	diagnosis_code5	APDC
diagnosis_code6	diagnosis_code6	APDC
diagnosis_code7	diagnosis_code7	APDC
diagnosis_code8	diagnosis_code8	APDC
diagnosis_code9	diagnosis_code9	APDC
diagnosis_code10	diagnosis_code10	APDC
diagnosis_code11	diagnosis_code11	APDC
diagnosis_code12	diagnosis_code12	APDC
diagnosis_code13	diagnosis_code13	APDC
diagnosis_code14	diagnosis_code14	APDC
diagnosis_code15	diagnosis_code15	APDC
diagnosis_code16	diagnosis_code16	APDC
diagnosis_code17	diagnosis_code17	APDC
diagnosis_code18	diagnosis_code18	APDC
diagnosis_code19	diagnosis_code19	APDC
diagnosis_code20	diagnosis_code20	APDC
diagnosis_code21	diagnosis_code21	APDC
diagnosis_code22	diagnosis_code22	APDC
diagnosis_code23	diagnosis_code23	APDC
diagnosis_code24	diagnosis_code24	APDC
diagnosis_code25	diagnosis_code25	APDC
diagnosis_code26	diagnosis_code26	APDC

diagnosis_code27	diagnosis_code27	APDC
diagnosis_code28	diagnosis_code28	APDC
diagnosis_code29	diagnosis_code29	APDC
diagnosis_code30	diagnosis_code30	APDC
diagnosis_code31	diagnosis_code31	APDC
diagnosis_code32	diagnosis_code32	APDC
diagnosis_code33	diagnosis_code33	APDC
diagnosis_code34	diagnosis_code34	APDC
diagnosis_code35	diagnosis_code35	APDC
diagnosis_code36	diagnosis_code36	APDC
diagnosis_code37	diagnosis_code37	APDC
diagnosis_code38	diagnosis_code38	APDC
diagnosis_codeE1	diagnosis_codeE1	APDC
diagnosis_codeE2	diagnosis_codeE2	APDC
diagnosis_codeP	diagnosis_codeP	APDC
episode_day_stay_los	episode_day_stay_los	APDC
episode_end_date	episode_end_date	APDC
episode_end_time	episode_end_time	APDC
episode_length_of_stay	episode_length_of_stay	APDC
episode_of_care_type	episode_of_care_type	APDC
episode_start_date	episode_start_date	APDC
episode_start_time	episode_start_time	APDC
facility_identifier_recode	facility_identifier_recode	APDC
facility_trans_from_recode	facility_trans_from_recode	APDC
facility_trans_to_recode	facility_trans_to_recode	APDC
financial_class	financial_class	APDC
health_insurance_on_admit	health_insurance_on_admit	APDC
marital_status	marital_status	APDC
mode_of_separation_recode	mode_of_separation_recode	APDC
payment_status_on_sep	payment_status_on_sep	APDC
peer_group	peer_group	APDC
procedure_code1	procedure_code1	APDC

procedure_code2	procedure_code2	APDC
procedure_code3	procedure_code3	APDC
procedure_code4	procedure_code4	APDC
procedure_code5	procedure_code5	APDC
procedure_code6	procedure_code6	APDC
procedure_code7	procedure_code7	APDC
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procedure_code16	procedure_code16	APDC
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procedure_code21	procedure_code21	APDC
procedure_code22	procedure_code22	APDC
procedure_code23	procedure_code23	APDC
procedure_code24	procedure_code24	APDC
procedure_code25	procedure_code25	APDC
procedure_code26	procedure_code26	APDC
procedure_code27	procedure_code27	APDC
procedure_code28	procedure_code28	APDC
procedure_codeP	procedure_codeP	APDC
procedure_dateP	procedure_dateP	APDC
project_recid	Project record sequence number for APDC	APDC

referred_to_on_separation_recode	referred_to_on_separation_recode	APDC
source_of_referral_recode	source_of_referral_recode	APDC
srg	srg	APDC
srg_version	srg_version	APDC
unit_type_on_admission	unit_type_on_admission	APDC
patient2	patient status	APDC
PPN_Baby	Person Project Number for baby	ABS (Death - baby)
age_dth_original	Age at death in fractional years as provided by ABS	ABS (Death - baby)
PPN_Baby	Person Project Number for baby	ABS (Death - baby)
date_dth	Date of death	ABS (Death - baby)
project_recid	Project record ID - ABS mortality	ABS (Death - baby)
PPN_baby	Project Person Number - baby	ABS (Perinatal deaths)
date_dth	Date of death	ABS (Perinatal deaths)
project_recid	Project record ID - ABS Perinatal deaths	ABS (Perinatal deaths)
PPN_baby	Project Person Number - baby	PDR (Baby)

PeriDthType	Type of perinatal death	PDR (Baby)
bdob	Baby date of birth	PDR (Baby)
date_dth	Date of death	PDR (Baby)
project_recid	Project record ID - Perinatal death review	PDR (Baby)
DATE_DTH	Date of death	RBDM (Baby)
PPN_Baby	Project Person Number (baby)	RBDM (Baby)
project_recid	Project record ID - RBDM death registrations	RBDM (Baby)
PPN_baby	Person Project Number - baby	RCC (Baby)
bdatedth	Baby's date of death	RCC (Baby)
bdob	Baby's date of birth	RCC (Baby)
project_recid	Project record ID - RoCC baby	RCC (Baby)
IDproj	Project ID (Mother)	MBS
benefit	Medicare benefit (rebate)	MBS
dos	Date of Service	MBS
item	Specific item number	MBS
nullrecord	nullrecord	MBS
prov	Provider unique number	MBS
year	year	MBS
charge	Amount charged by the provider	MBS

Data dictionary for ALSWH datasets

Variable name	Variable description	Format
PPN_mum	Project ID for mother	Number
PPN_baby	Project ID for baby	Number
datesurveyreturned	Participant status	Date
age	Age	Continuous
marital	Marital status (marital)	1 = Married 2 = De-facto 3 = Separated 4 = Divorced 5 = Widowed 6 = Single
ariapgp	Accessibility/Remoteness Index of Australia (ARIA+) grouped	1= Major cities of Australia 2= Inner regional Australia 3= Outer regional Australia 4= Remote Australia 5= Very remote Australia 6= Overseas participants
rrma	Rural, remote and metropolitan areas (RRMA) classification	1= Capital city 2= Other Metropolitan centre 3= Large rural centre 4= Small rural centre 5= Other rural centre 6= Remote centre 7= Other remote area
education	Highest qualification completed	1= No formal qualifications 2= School certificate

		(Year 10 or equivalent) 3= Higher School Certificate (Year 12 or equivalent) 4= Trade/apprenticeship (eg Haridresser, Chef) 5= Certificate/diploma (eg Child Care, Technician) 6= University degree Higher University degree (eg Grad Dip, Masters, PhD)
hrswork	Hours worked (NOTE: Response 7 - not in labour force/unemployed is not in young 2)	1= 1-15 hrs 2= 16-24 hrs 3= 25-34 hrs 4= 35-40 hrs 5= 41-48 hrs 6= 49+ hrs 7= not in labour force / unemployed
Income2	What is the average gross (before tax) income that you receive each week, including pensions, allowances and financial support from parents?	1= No Income 2= $1 - $119 ($1-$6.239 annually) 3= $120 - $299 per week ($6,420 - $15,999 annually) 4= $300 - $499 per week ($16,000 - $25,999 annually) 5= $500 - $699 per week ($26,000 - $36,999 annually)

		6= $700 - $999 per week ($37,000 - $51,999 annually) 7= $1,000 - $1,499 per week ($52,000 - $77,999 annually) 8= $1,500 or more per week ($78,000 or more annually) 9= Don't know 10= Don't want to answer
seifaadv	Socio-economic index for areas (SEIFA) Index Socio-economic Advantage/Disadvantage	Continuous (higher score indicates more advantage)
seifaocc	SEIFA index of Education and Occupation	Continuous (higher score indicates more education)
seifadis	SEIFA Index Socio-economic Disadvantage	Continuous (higher score indicates less disadvantage)
smokst	Smoking status - smokst	1= Never-smoker 2= Ex-smoker 3= Smoker, less than 10 per day 4= Smoker, 10-19 per day 5= Smoker, 20 or more per day 6= Smoker, unknown cigarettes per day
oftensmoke	How often do you currently smoke cigarettes or any tobacco products?	1= Daily 2= At least weekly (but not daily)

		3= Less often than weekly 4= Not at all
oftendrink	How often do you usually drink alcohol?	1= I never drink alcohol 2= Less than once a month / I drink rarely 3= Less than once a week 4= On 1 or 2 days a week 5= On 3 or 4 days a week 6= On 5 or 6 days a week 7= Every day
Nhmrc	National Health and Medical Research Council (NHMRC) alcohol classification	1= 'Low risk drinker' 2= 'Non-drinker' 3= 'Rarely drinks' 4= 'Risky drinker' 5= 'High risk drinker'
alcpattern	Alcohol drinking pattern	1= 'Low long-term risk, drinks at short-term risk less than weekly' 2= 'Non-drinker' 3= 'Low long-term risk, drinks at short-term risk weekly or more' 4= 'Risky/high risk drinker'
bmi	Body Mass Index (BMI)	Continuous
wgt	Weight (in kgs)	Weight in kilograms
hgt	Height (in cms)	Height in centimetres
bmiclass	BMI classification	1= Underweight 2= Acceptable weight 3= Overweight 4= Obese

metsmins	Exercise score (metsmins)	Continuous (higher score indicates more exercise)
exercisegrp	Exercise group	1= 'Nil/sedentary' 2= 'Low' 3= 'Moderate' 4= 'High'
marijuana	Have you used it in the last 12 months? Marijuana (cannabis, hash, grass, dope, pot, yandi)	1= Yes 0= No
drugpa	Pattern of Drug Use	1= Never used illicit drugs 2= ONLY ever used Marijuana - not in last 12mths 3= ONLY ever used Marijuana - used in the last 12mths 4= Used multiple/single drug other than Marijuana-not last12mths 5= Used multiple/single drug other than Marijuana->=1 last 12mths
drugus	Drug Use	0= Never used illicit drugs 1= Used illicit drugs
partvio	These questions are about getting on with other people: Have you ever been in a	1= Yes 2= No 3= I prefer not to answer (y6)

	violent relationship with a partner/spouse?	8= Never had partner or spouse (y5)
emoabuse	Emotional Abuse Scale Higher number indicates more abuse	0-55 88
harrassment	Harrassment Abuse Scale Higher number indicates more abuse	0-20 88
phyabuse	Physical Abuse Scale Higher number indicates more abuse	0-35 88
sevabuse	Severe Abuse Scale Higher number indicates more abuse	0-30 88
mosaffg	Grouped Mean value of the Medical Outcomes Study Support Index (MOS) scale values for Affectionate Support, 1 to 5. Higher scores for subscales and the index indicate more social support.	1= All of the time 2= Most of the time 3= Some of the time 4= None or a little of the time
mosemog	Grouped Mean value of MOS scale values for Emotional/Informational Support, 1 to 5. Higher scores for subscales and the index indicate more social support.	1= All of the time 2= Most of the time 3= Some of the time 4= None or a little of the time

mossocsupg	Grouped Mean value of MOS scale values for Positive Social Interaction, 1 to 5. Higher scores for subscales and the index indicate more social support.	1= All of the time 2= Most of the time 3= Some of the time 4= None or a little of the time
mostangg	Grouped Mean value of MOS scale values for Tangible Support, 1 to 5 Higher scores for subscales and the index indicate more social support.	1= All of the time 2= Most of the time 3= Some of the time 4= None or a little of the time
mosaff	Mean value of MOS scale values for Affectionate Support, 1 to 5	1 to 5
mosemo	Mean value of MOS scale values for Emotional/Informational Support, 1 to 5	1 to 5
mossocsup	Mean value of MOS scale values for Positive Social Interaction, 1 to 5	1 to 5
mostang	Mean value of MOS scale values for Tangible Support, 1 to 5	1 to 5
Lotr	The 6-item sum is referred to as the Revised Life Orientation Test (LOT-R) score. Higher scores indicate a more optimistic outlook.	1= Strongly disagree 2= Disagree 3= Neutral 4= Agree 5= Strongly agree

occupation	We would like to know your main occupation now:	1= Manager or administrator 2= Professional 3= Associate professional 4= Tradesperson or related worker 5= Advanced clerical or service worker 6= Intermediate clerical, sales/service worker 7= Intermediate production or transport worker 8= Elementary clerical, sales or service worker 9= Labourer or related worker 10= No paid job
nummisc	Number of Miscarriages	0 1 2 3 4 5+
termmed	How many times have you had each of the following? Termination (abortion) for medical reasons (eg fetal abnormalities)	0= None 1= One 2= Two 3= Three 4= Four 5= 5 or more
termoth	Termination (abortion) for other reasons	0= None 1= One

		2= Two 3= Three 4= Four 5= 5 or more
numterms	Number of terminations	0 1 2 3 4 5+
numbirths	Number of Births	0 1 2 3 4 5+
infertility	Have you and your partner (current or previous) ever had problems with infertility (that is, tried unsuccessfully to get pregnant for 12 months or more)?	1= Never tried to get pregnant 2= No problem with infertility 3= Yes, but have not sought help/treatment 4= Yes, and have sought help/treatment
tubal	Do any of the following apply to you? I have had a tubal ligation	1= Yes 2= No
ivf	Do any of the following apply to you? I am using/have used In Vitro Fertilisation (IVF)	1= Yes 2= No

ferthorm	Do any of the following apply to you? I am using/have used fertility hormones (eg Clomid)	1= Yes 2= No
hypertension	Have you ever been told by a doctor that you have: Hypertension (high blood pressure) during pregnancy Ever (Survey 1) In last 4 years (Survey 2) In last 3 years (Survey 3-6)	1= Yes 0= No (from coding)
asthma	In the past three years, have you been diagnosed with or treated for: Asthma	1= Yes 0= No (from coding)
endometriosis	In the last 3 years, have you been diagnosed or treated for: Endometriosis	1= Yes 0= No
heartdisease	Have you ever been told by a doctor that you have: Heart Disease (Survey 1) In last 4 years (Survey 2) In last 3 years (Survey 3-6)	1= Yes 0= No (from coding)
pos	In the last 3 years, have you been diagnosed or treated for:	1= Yes 0= No (from coding)

	Polycystic Ovary Syndrome	
uti	In the last 3 years, have you been diagnosed or treated for: Urinary tract infection	1= Yes 0= No
Cancer5	Have you ever been told by a doctor that you have: Cancer	1= Yes 0= No (default)
Sti	Have you been diagnosed or treated for: Sexually transmitted infection (eg genital herpes or warts, chlamydia) Ever (survey 1) Past 4 years (survey 2) In past 3 years (Survey 3-5)	3= Don't know 1= Yes 0= No
Depression	In the past three years, have you been diagnosed or treated for: Depression (not postnatal) Survey 2 - last 4 years Survey 3-6 - last 3 years	1= Yes 0= No (default)
pnd	Postnatal depression (PND) Survey 2 (last 4 years) Survey 3,4 (last 3 years) Survey 5,6 (for each delivery)	1= Yes 0= No (default)

anxiety	In the past three years, have you been diagnosed with or treated for: Anxiety/nervous disorder	1= Yes 0= No (from coding)
Intanx2	In the last 12 months, have you had any of the following: Episodes of intense anxiety (eg panic attacks)	1= Never (No) 2= Rarely 3= Sometimes 4= Often
cesd10	Centre for Epidemiology Studies Depression Scale (CES-D10)	Continuous (higher score indicates more depression)
anxgad	Goldberg Anxiety and Depression Scale	1 to 9 (Higher value means more stress)
stress	Mean stress score	0,1,2,3,4 (Higher value means more stress)
ownhealthstress	Over the last 12 months, how stressed have you felt about the following areas of your life: Own health	1= Not applicable 2= Not at all stressed 3= Somewhat stressed 4= Moderately stressed 5= Very stressed 6= Extremely stressed
relstress	Over the last 12 months, how stressed have you felt about the following areas of your life: Relationship with partner/spouse	1= Not Applicable 2= Not at all Stressed 3= Somewhat Stressed 4= Moderately Stressed 5= Very Stressed 6= Extremely Stressed
mumstress	Over the last 12 months, how stressed have you felt	1= Not Applicable 2= Not at all Stressed

	about the following areas of your life: Motherhood/children	3= Somewhat Stressed 4= Moderately Stressed 5= Very Stressed 6= Extremely Stressed
consultgp2	Consult GP	0= None 1= 1-2 times 2= 3-4 times 3= 5-6 times 4= 7-9 times 5= 10-12 times 6= More than 12 times
consulthospdr2	Have you consulted the following people for your own health in the last 12 months? A hospital doctor (eg. in outpatients or casualty)	1= Yes 2= No
specialist5	Have you consulted a specialist for your own health in the last 12 months? A specialist doctor	0= No 1= Yes
gpstfy	GP satisfaction score (gpstfy)	1-5, higher score indicates higher satisfaction
accessmed	Thinking about your own health care, how would you rate the following: Access to medical	1= Excellent 2= Very good 3= Good 4= Fair 5= Poor 6= Don't Know

	specialists if you need them	
accesshosp	Thinking about your own health care, how would you rate the following: Access to a hospital if you need it	1= Excellent 2= Very good 3= Good 4= Fair 5= Poor 6= Don't Know
accessafterhrsmed	Thinking about your own health care, how would you rate the following: Access to after-hours medical care	1= Excellent 2= Very good 3= Good 4= Fair 5= Poor 6= Don't Know
accessgpbb	Thinking about your own health care, how would you rate the following: Access to a GP who bulk bills	1= Excellent 2= Very good 3= Good 4= Fair 5= Poor 6= Don't Know
accessfemgp	Thinking about your own health care, how would you rate the following: Access to a female GP	1= Excellent 2= Very good 3= Good 4= Fair 5= Poor 6= Don't Know
prihealthhosp	Do you have private health insurance for hospital cover? If not, mark the main reason why.	1= Yes 2= No - because I can't afford the cost 3= No - because I don't think you get value for money 4= No - because I don't

		think I need it 5= No - other reason
prihealth	Do you have private health insurance for hospital cover?	1=Yes 0=No
prihealthanc	Do you have private health insurance for ancillary services (eg dental, physiotherapy)? If not, mark the main reason why.	1= Yes 2= No - because I can't afford the cost 3= No - because I don't think you get value for money 4= No - because I don't think I need it 5= No - because the services are not available where I live 6= No - other reason
healthcarecard	Do you have a Health Care Card ? This is a card that entitles you to discounts and assistance with medical expenses. This is not the same as a Medicare card.	1= Yes 2= No
hospprobpreg	Have you been admitted to hospital in the last 12 months for any of these reasons? Problems during pregnancy	1= Yes 0= No (from coding)

Hospoth2	Have you been admitted to hospital in the last 12 months for any of these reasons? All other reasons	1= Yes 0= No (from coding)
type1diab	In the past three years, have you been diagnosed or treated for: Insulin dependent (type 1) diabetes	1= Yes 0= No (from coding)
type2diab	In the past three years, have you been diagnosed or treated for: Insulin dependent (type 2) diabetes	1= Yes 0= No (from coding)
diabetes	Diabetes	1= Yes 0= No (from coding)
antedepress	Antenatal depression	1= Yes 0= No
antenatalanxiety	Antenatal anxiety	1= Yes 0= No
breastfed	Months of breastfeeding	Discrete for months
cbirthdate	Child's date of birth	Date
electivecaesar	Elective caesarean	1= Yes 0= No
emergencycaesar	Emergency caesarean	1= Yes 0= No
epidural	Epidural use - pain relief	1= Yes 0= No

episiotomy	Episiotomy	1= Yes 0= No
forceps	Forceps during delivery	1= Yes 0= No
gas	Gas - pain relief	1= Yes 0= No
gesdiabetes	Gestational diabetes	1= Yes 0= No
induct	Induction	1= Yes 0= No
lbw	Low birth weight	1= Yes 0= No
postnatalanxiety	Postnatal anxiety	1= Yes 0= No
postnataldepress	Postnatal depression	1= Yes 0= No
prembirth	Premature birth	1= Yes 0= No
stillbth	Stillbirth	1= Yes 0= No
vaginaltear	Vaginal tear	1= Yes 0= No
prevab	Previous adverse birth	1 = Yes 0 = No
ICU	Did baby require special care?	1= Yes 0= No
Prevstillbth	Previous stillbirth	1 = Yes 0 = No
Prevprem	Previous premature birth	1 = Yes 0 = No
Prevlbw	Previous low birth weight	1 = Yes 0 = No

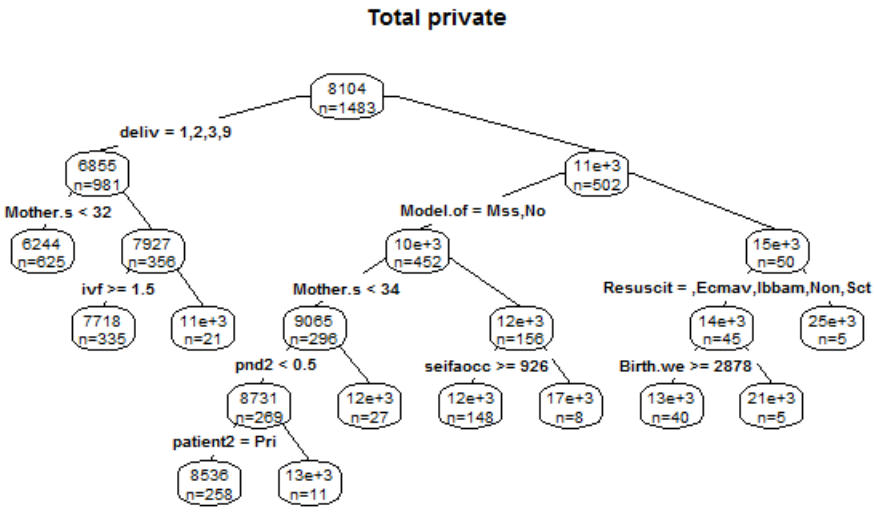
ab	Adverse birth	1= Yes 0= No

Appendix B

Selected factors for hospital costing study from CART

Private Total

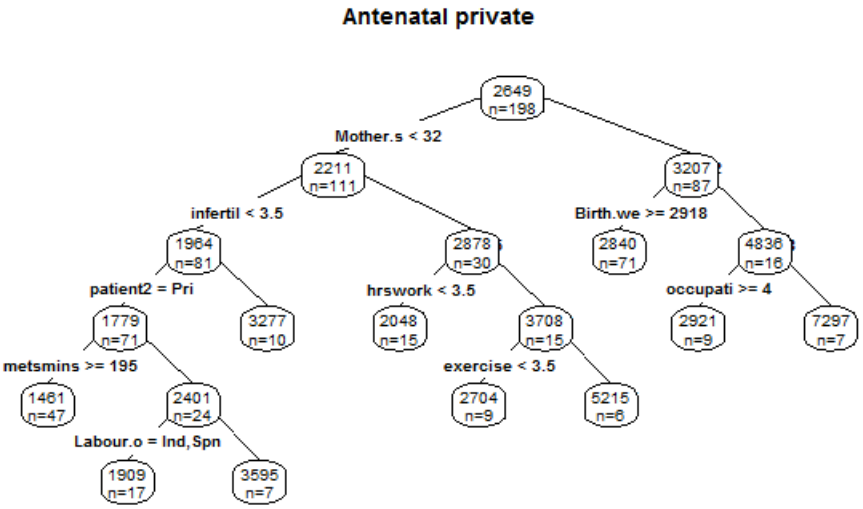
Variables actually used in tree construction:
[1] Birth.weight..grams.
[2] deliv
[3] ivf
[4] Model.of.care.birth...hospital.based.medical
[5] Mother.s.age
[6] patient2
[7] pnd2
[8] Resuscitation.of.baby
[9] seifaocc



Private Antenatal

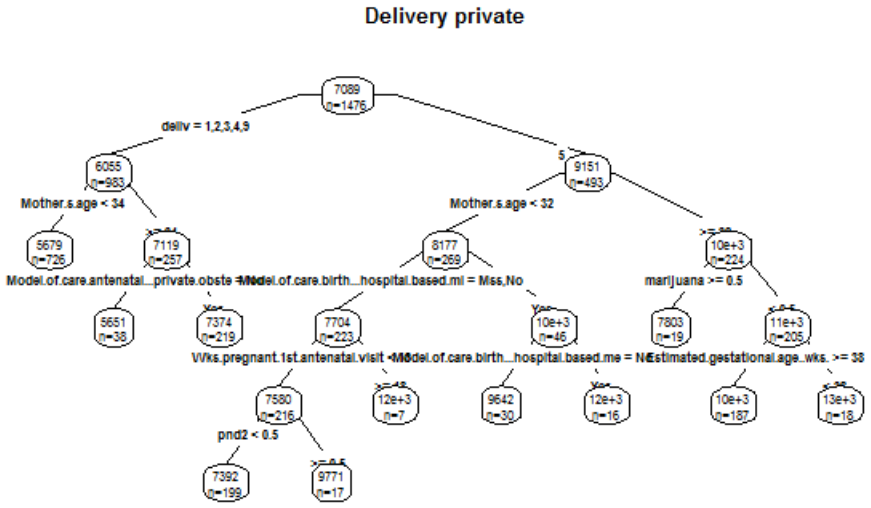
Variables actually used in tree construction:
[1] accessgpbb
[2] alcpattern
[3] Birth.weight..grams.

[4] cesd10
[5] Cigarettes.per.day...2nd.half
[6] exercisegrp
[7] hospoth2
[8] hrswork
[9] infertility
[10] Labour.onset
[11] lotr
[12] metsmins
[13] Model.of.care.birth...hospital.based.midwife
[14] mosaff
[15] mossocsup
[16] Mother.s.age
[17] occupation
[18] pain_epi2
[19] patient2
[20] Resuscitation.of.baby
[21] rrma
[22] uti



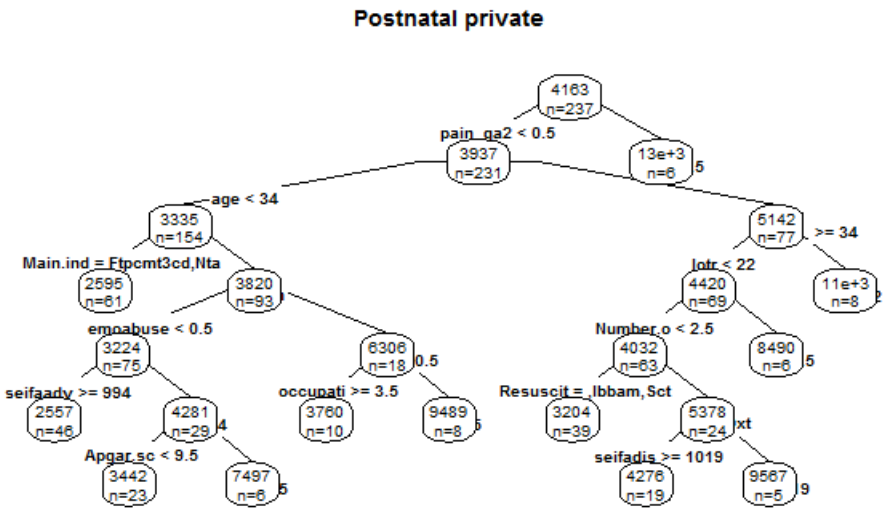
Private Delivery

Variables actually used in tree construction:
[1] deliv
[2] Estimated.gestational.age..wks.
[3] marijuana
[4] Model.of.care.antenatal...private.obstetrician
[5] Model.of.care.birth...hospital.based.medical
[6] Model.of.care.birth...hospital.based.midwife
[7] Mother.s.age
[8] pnd2
[9] Wks.pregnant.1st.antenatal.visit



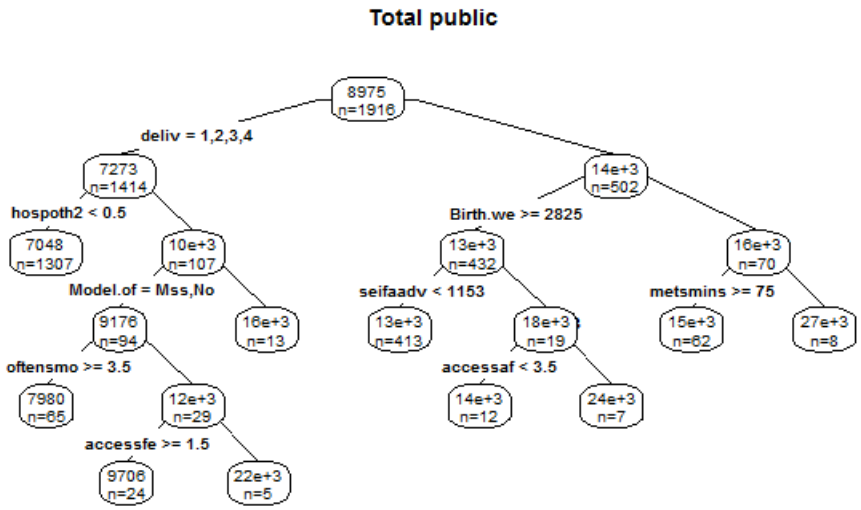
Private Postnatal

Variables actually used in tree construction:
[1] age
[2] Apgar.score..5.min..
[3] emoabuse
[4] lotr
[5] Main.indication.for.caesarean.section
[6] Number.of.previous.pregnancies
[7] occupation
[8] pain_ga2
[9] Resuscitation.of.baby
[10]seifaadv
[11]seifadis



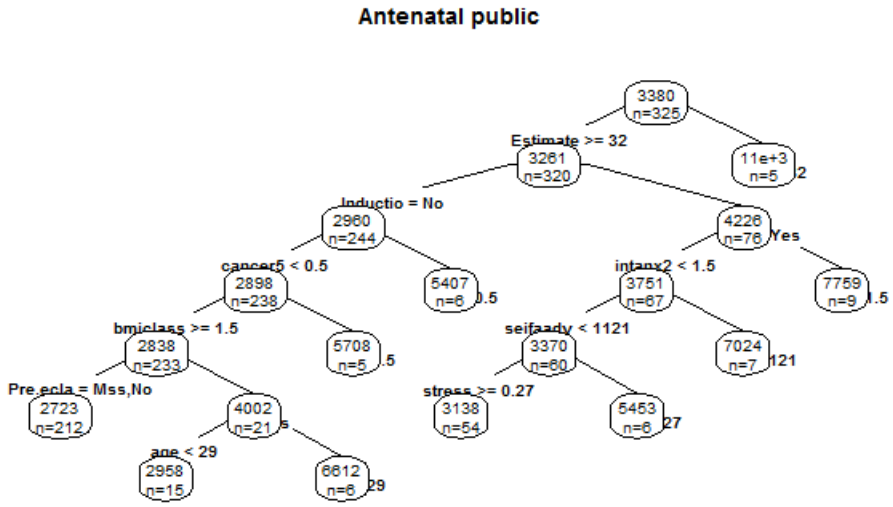
Public Total

Variables actually used in tree construction:
[1] accessafterhrsmed
[2] accessfemgp
[3] Birth.weight..grams.
[4] deliv
[5] hospoth2
[6] metsmins
[7] Model.of.care.antenatal...private.obstetrician
[8] oftensmoke
[9] seifaadv



Public Antenatal

Variables actually used in tree construction:
[1] age
[2] bmiclass
[3] cancer5
[4] Estimated.gestational.age..wks.
[5] Induction.augmentation.by.oxytocics
[6] intanx2
[7] Pre.eclampsia
[8] seifaadv
[9] stress



Public Delivery

Variables actually used in tree construction:
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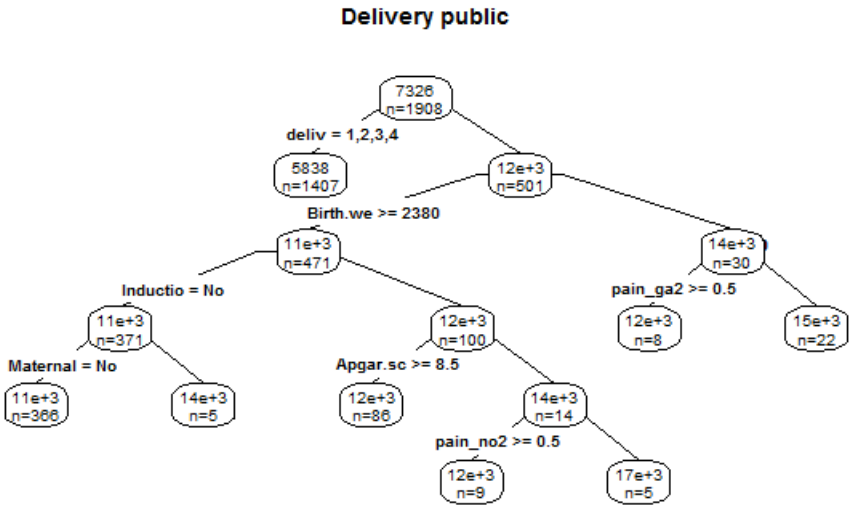
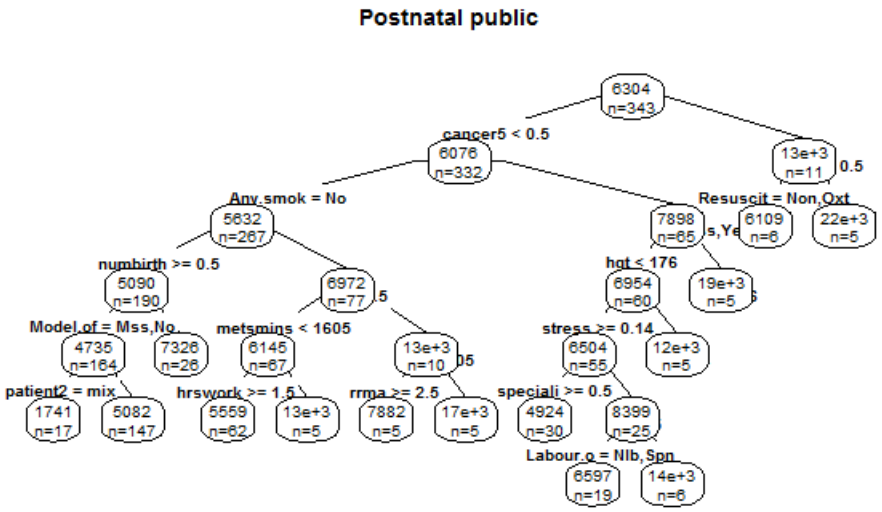
[2] Birth.weight..grams.
[3] deliv
[4] Induction.augmentation.by.oxytocics
[5] Maternal.diabetes.mellitus.
[6] pain_ga2
[7] pain_no2



Public Postnatal

Variables actually used in tree construction:
[1] Any.smoking.during.pregnancy.
[2] cancer5
[3] hgt

[4] hrswork
[5] Labour.onset
[6] metsmins
[7] Model.of.care.antenatal...private.obstetrician
[8] numbirths
[9] patient2
[10] Resuscitation.of.baby
[11] rrma
[12] specialist5
[13] stress



Appendix C

Model refit using negative binomial distribution and backward stepwise selection for hospital costing study

Negative binomial model refit (log link, <0.01% significance) for Private Total

Coefficients	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	8.555	0.151	56.84	0.00E+00
deliv2	0.048	0.042	1.14	2.56E-01
deliv3	-0.002	0.032	-0.06	9.53E-01
deliv4	0.300	0.178	1.69	9.13E-02
deliv5	0.396	0.019	20.33	6.70E-92
age	0.037	0.004	10.36	3.79E-25
ivf	-0.329	0.041	-8.10	5.64E-16
patient2Pri	-0.274	0.050	-5.50	3.81E-08

Backward stepwise selections for Private Total

Coefficients	Estimate	Std. Error	t value	Pr(>|t|)	Selected stepwise	Original selection
(Intercept)	8.75E+00	0.324	27.03	7.64E-114		
cancer5	-1.65E-01	0.134	-1.23	2.19E-01	Yes	Yes
intanx2	3.55E-02	0.024	1.45	1.49E-01	No	No
seifaadv	2.37E-04	0.0001	1.50	1.35E-01	No	No
age	2.29E-02	0.007	3.44	6.12E-04	Yes	Yes
bmi	4.33E-03	0.003	1.49	1.38E-01	No	No
hospoth2	1.42E-01	0.048	2.98	3.00E-03	No	No
hrswork	-7.91E-03	0.006	-1.27	2.06E-01	No	No
occupation	-9.94E-03	0.004	-2.36	1.84E-02	No	No
oftendrink	-1.70E-02	0.009	-1.81	7.08E-02	No	No
accessmed	1.50E-02	0.012	1.29	1.99E-01	No	No
accessfemgp	-1.20E-02	0.010	-1.22	2.24E-01	No	No
ivf	-3.47E-01	0.067	-5.20	2.54E-07	Yes	Yes
deliv2	-6.01E-02	0.068	-0.88	3.80E-01	No	No
deliv3	-2.57E-02	0.047	-0.55	5.81E-01	No	No
deliv4	3.33E-01	0.220	1.52	1.30E-01	No	No
deliv5	3.61E-01	0.030	11.99	1.75E-30	Yes	No
patient2Pri	-2.79E-01	0.070	-3.99	7.24E-05	Yes	Yes

Negative binomial model refit (log link, <0.01% significance) for Public Delivery

Coefficients	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	8.642	0.022	396.56	0.00E+00
deliv2	0.089	0.023	3.89	1.02E-04
deliv3	0.041	0.016	2.53	1.16E-02
deliv4	0.097	0.052	1.85	6.49E-02
deliv5	0.685	0.012	55.73	0.00E+00
Labour.onsetNo labour	-0.043	0.016	-2.72	6.44E-03
Labour.onsetSpontaneous	-0.011	0.009	-1.14	2.54E-01
prihealth	0.029	0.008	3.49	4.87E-04
smokst	0.012	0.004	3.36	7.82E-04
Baby.s.place.of.birthBorn before arrival	-0.205	0.047	-4.37	1.27E-05
Baby.s.place.of.birthHospital	0.017	0.018	0.94	3.47E-01
Baby.s.place.of.birthPlanned BC/hosp adm	-0.016	0.035	-0.45	6.55E-01
ariapgp	-0.011	0.005	-2.36	1.83E-02
Maternal.diabetes.mellitus.Yes	0.121	0.041	2.98	2.84E-03
ab	0.074	0.0150	4.91	9.11E-07

Backward stepwise selections for Public Delivery

Coefficients	Estimate	Std. Error	t value	Pr(>|t|)	Selected stepwise	Original selection [14]
(Intercept)	8.510	0.049	172.86	0.00E+00		
Maternal.diabetes.mellitus.Yes	0.114	0.061	1.88	6.08E-02	No	Yes
intanx2	0.018	0.009	1.93	5.39E-02	No	No
drugpa	-0.010	0.005	-2.04	4.14E-02	No	N
deliv2	0.096	0.035	2.72	6.60E-03	No	No
deliv3	0.082	0.026	3.16	1.64E-03	No	No
deliv4	0.195	0.077	2.53	1.15E-02	No	No
deliv5	0.701	0.020	35.38	3.50E-165	Yes	Yes
Labour.onsetNo labour	-0.061	0.025	-2.50	1.28E-02	No	Yes
Labour.onsetSpontaneous	-0.016	0.015	-1.06	2.91E-01	No	No
prihealth	0.038	0.013	2.92	3.58E-03	No	Yes
smokst	0.027	0.007	3.89	1.09E-04	Yes	Yes
Baby.s.place.of.birthBorn before arrival	-0.577	0.102	-5.67	2.05E-08	Yes	Yes
Baby.s.place.of.birthHospital	-0.002	0.027	-0.07	9.42E-01	No	No
Baby.s.place.of.birthPlanned BC/hosp adm	-0.030	0.053	-0.57	5.70E-01	No	No
oftendrink	0.012	0.004	2.78	5.50E-03	No	No
ab	0.094	0.025	3.80	1.54E-04	Yes	Yes
patient2Oth	0.258	0.091	2.84	4.59E-03	No	No
patient2Pub	0.076	0.031	2.42	1.57E-02	No	No

[14] Note ariapgp was also selected in the original model but was not picked up by the backward stepwise selection procedure

Appendix D

GLMM output for hospital costing study (delivery models only)

Public Delivery - One Random Effect (baby's place of birth)

```
Random effects:
 Formula: ~1 | Baby.s.place.of.birth
        (Intercept) Residual
StdDev:      0.0714     0.17

Variance function:
 Structure: fixed weights
 Formula: ~invwt
Fixed effects: hospdeliverycost ~ +deliv + Labour.onset + prihealth
+ deliv +      smokst + ab + Maternal.diabetes.mellitus. + ariapgp
                               Value Std.Error   DF t-value p-value
(Intercept)                     8.60    0.0413 1715   208.1  0.0000
deliv2                          0.09    0.0250 1715     3.6  0.0004
deliv3                          0.04    0.0178 1715     2.3  0.0197
deliv4                          0.10    0.0572 1715     1.7  0.0898
deliv5                          0.69    0.0134 1715    51.0  0.0000
Labour.onsetNo labour          -0.04    0.0171 1715    -2.5  0.0126
Labour.onsetSpontaneous        -0.01    0.0100 1715    -1.1  0.2781
prihealth                       0.03    0.0092 1715     3.2  0.0014
smokst                          0.01    0.0039 1715     3.0  0.0024
ab                              0.07    0.0164 1715     4.4  0.0000
Maternal.diabetes.mellitus.Yes  0.12    0.0445 1715     2.7  0.0064
ariapgp                        -0.01    0.0052 1715    -2.2  0.0257
```

Public Delivery - Multiple Random Effects

```
Random effects:
 Formula: ~1 | Baby.s.place.of.birth
        (Intercept)
StdDev:      0.0856

 Formula: ~1 | Local.Health.District.of.hospital %in% Baby.s.place.o
f.birth
        (Intercept)
StdDev:    2.33e-06

 Formula: ~1 | Hospital.Obstetric.Level %in% Local.Health.District.o
f.hospital %in% Baby.s.place.of.birth
        (Intercept)
StdDev:      0.0184

 Formula: ~1 | Health.Area..2005..of.hospital %in% Hospital.Obstetri
c.Level %in% Local.Health.District.of.hospital %in% Baby.s.place.of.
birth
        (Intercept)
StdDev:      0.0184

 Formula: ~1 | Health.Area..1996..of.hospital %in% Health.Area..2005
..of.hospital %in% Hospital.Obstetric.Level %in% Local.Health.Distri
ct.of.hospital %in% Baby.s.place.of.birth
        (Intercept)
StdDev:    2.89e-05

 Formula: ~1 | Hospital %in% Health.Area..1996..of.hospital %in% Hea
lth.Area..2005..of.hospital %in% Hospital.Obstetric.Level %in% Local
.Health.District.of.hospital %in% Baby.s.place.of.birth
        (Intercept) Residual
StdDev:       0.027    0.169
```

```
Variance function:
 Structure: fixed weights
 Formula: ~invwt
Fixed effects: hospdeliverycost ~ +deliv + Labour.onset + prihealth
+ deliv +      smokst + ab + alcpattern + Maternal.diabetes.mellitus
.
                                  Value Std.Error   DF t-value p-value
(Intercept)                        8.59    0.0475 1705   181.0  0.0000
deliv2                             0.08    0.0238 1705     3.3  0.0009
deliv3                             0.04    0.0177 1705     2.0  0.0463
deliv4                             0.08    0.0572 1705     1.4  0.1650
deliv5                             0.68    0.0129 1705    53.2  0.0000
Labour.onsetNo labour             -0.04    0.0164 1705    -2.3  0.0233
Labour.onsetSpontaneous           -0.01    0.0096 1705    -1.0  0.3185
prihealth                          0.03    0.0089 1705     3.7  0.0002
smokst                             0.01    0.0039 1705     2.8  0.0049
ab                                 0.08    0.0160 1705     4.8  0.0000
alcpattern                        -0.01    0.0057 1705    -1.7  0.0961
Maternal.diabetes.mellitus.Yes     0.12    0.0433 1705     2.7  0.0065
```

Private Delivery - One Random Effect (baby's place of birth)

```
Linear mixed-effects model fit by maximum likelihood
 Data: pridel
  AIC BIC logLik
   NA  NA     NA

Random effects:
 Formula: ~1 | Baby.s.place.of.birth
        (Intercept) Residual
StdDev:      0.0676    0.221

Variance function:
 Structure: fixed weights
 Formula: ~invwt
Fixed effects: hospdeliverycost ~ +deliv + Model.of.care.antenatal..
.private.obstetrician +      ivf + age
                              Value Std.Error   DF t-value p-value
(Intercept)                    7.71    0.1176 1171    65.6  0.0000
deliv2                         0.01    0.0308 1171     0.4  0.6638
deliv3                         0.03    0.0237 1171     1.2  0.2201
deliv4                         0.10    0.1300 1171     0.8  0.4326
deliv5                         0.40    0.0143 1171    27.7  0.0000
Model.of.care.antenatal..No    0.08    0.0256 1171     3.1  0.0023
Model.of.care.antenatal..Yes   0.06    0.0183 1171     3.4  0.0008
ivf                           -0.08    0.0295 1171    -2.6  0.0082
age                            0.03    0.0027 1171    11.6  0.0000
```

Private Delivery - Multiple Random Effects

```
Random effects:
 Formula: ~1 | Baby.s.place.of.birth
        (Intercept)
StdDev:      0.0795

 Formula: ~1 | Local.Health.District.of.hospital %in% Baby.s.place.o
f.birth
        (Intercept)
StdDev:    6.52e-12

 Formula: ~1 | Hospital.Obstetric.Level %in% Local.Health.District.o
f.hospital %in% Baby.s.place.of.birth
        (Intercept)
StdDev:    5.33e-05

 Formula: ~1 | Health.Area..2005..of.hospital %in% Hospital.Obstetri
c.Level %in% Local.Health.District.of.hospital %in% Baby.s.place.of.
birth
        (Intercept)
StdDev:    5.33e-05

 Formula: ~1 | Health.Area..1996..of.hospital %in% Health.Area..2005
..of.hospital %in% Hospital.Obstetric.Level %in% Local.Health.Distri
ct.of.hospital %in% Baby.s.place.of.birth
        (Intercept)
StdDev:      0.0636

 Formula: ~1 | Hospital %in% Health.Area..1996..of.hospital %in% Hea
lth.Area..2005..of.hospital %in% Hospital.Obstetric.Level %in% Local
.Health.District.of.hospital %in% Baby.s.place.of.birth
        (Intercept) Residual
StdDev:      0.0139    0.209

Variance function:
 Structure: fixed weights
```

```
 Formula: ~invwt
Fixed effects: hospdeliverycost ~ +deliv + Model.of.care.antenatal..
.private.obstetrician +      ivf + age
                               Value Std.Error   DF t-value p-value
(Intercept)                     7.70    0.1168 1084    65.9  0.0000
deliv2                          0.00    0.0298 1084     0.1  0.8895
deliv3                          0.03    0.0228 1084     1.3  0.1849
deliv4                          0.09    0.1282 1084     0.7  0.4833
deliv5                          0.39    0.0138 1084    28.1  0.0000
Model.of.care.antenatal...No    0.03    0.0271 1084     1.0  0.3423
Model.of.care.antenatal...Yes   0.07    0.0179 1084     4.1  0.0000
ivf                            -0.08    0.0282 1084    -2.8  0.0056
age                             0.03    0.0027 1084    12.2  0.0000
```

Appendix E

Severity GLMM output for hospital costing study

Private Delivery

```
Random effects:
 Formula: ~1 | Baby.s.place.of.birth
        (Intercept) Residual
StdDev:       0.147    0.212

Variance function:
 Structure: fixed weights
 Formula: ~invwt
Fixed effects: hospdeliverycost/X_FREQ_ ~ +deliv + age
            Value Std.Error   DF t-value p-value
(Intercept)  7.56    0.0931 1464    81.2   0.000
deliv2       0.02    0.0255 1464     0.9   0.342
deliv3       0.02    0.0196 1464     1.1   0.252
deliv4      -0.18    0.1251 1464    -1.5   0.144
deliv5       0.40    0.0125 1464    32.3   0.000
deliv9       0.20    0.2135 1464     0.9   0.350
age          0.03    0.0017 1464    17.0   0.000
```

Public Delivery

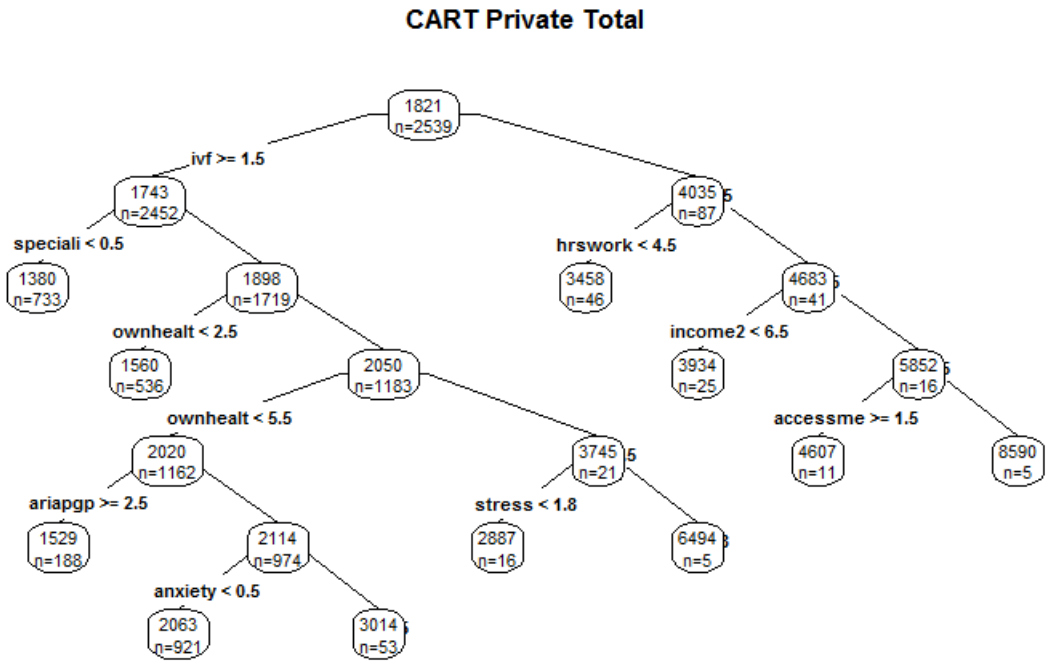
```
Random effects:
 Formula: ~1 | Baby.s.place.of.birth
        (Intercept) Residual
StdDev:      0.0809    0.175

Variance function:
 Structure: fixed weights
 Formula: ~invwt
Fixed effects: hospdeliverycost/X_FREQ_ ~ +deliv + Maternal.diabetes
.mellitus.
                                Value Std.Error   DF t-value p-value
(Intercept)                      8.55    0.0429 1899   199.1  0.0000
deliv2                           0.01    0.0243 1899     0.2  0.8351
deliv3                           0.03    0.0179 1899     1.8  0.0686
deliv4                           0.10    0.0588 1899     1.6  0.1018
deliv5                           0.66    0.0094 1899    70.4  0.0000
Maternal.diabetes.mellitus.Yes   0.15    0.0442 1899     3.4  0.0006
```

Appendix F

Selected factors for out-of-hospital costing study from CART - small

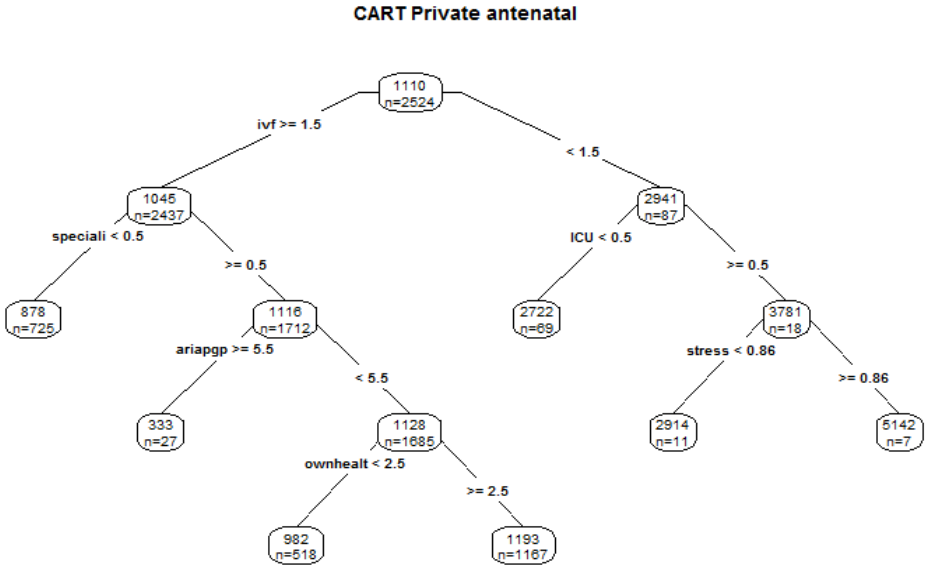
Private Total

Variables actually used in tree construction:
[1] accessmed
[2] anxiety
[3] ariapgp
[4] hrswork
[5] income2
[6] ivf
[7] ownhealthstress
[8] specialist5
[9] stress



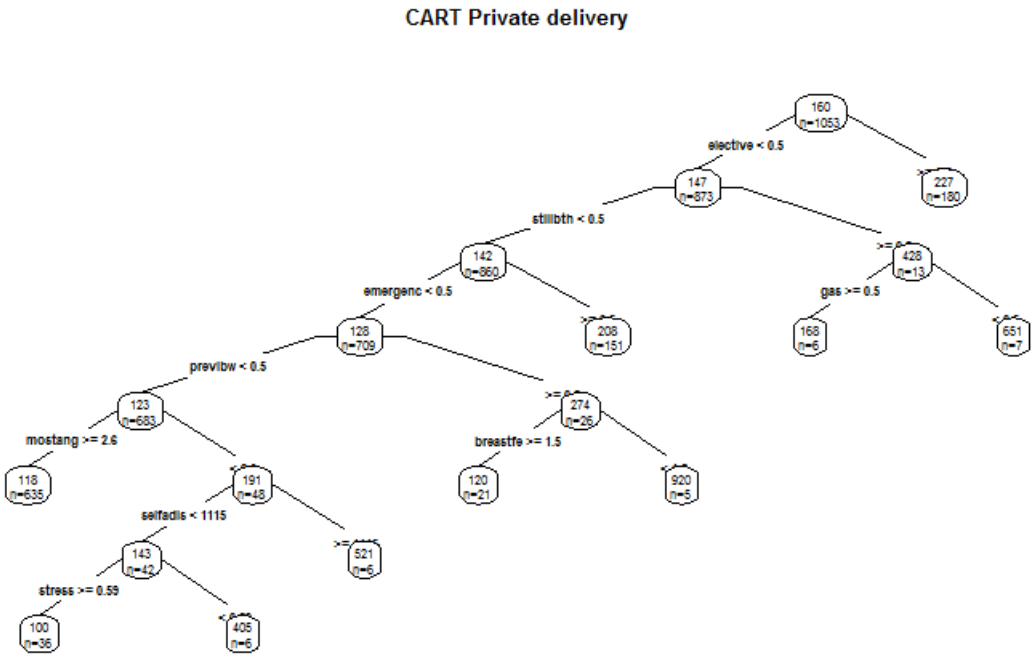
Private Antenatal

Variables actually used in tree construction:
[1] ariapgp
[2] ICU
[3] ivf
[4] ownhealthstress
[5] specialist5
[6] stress



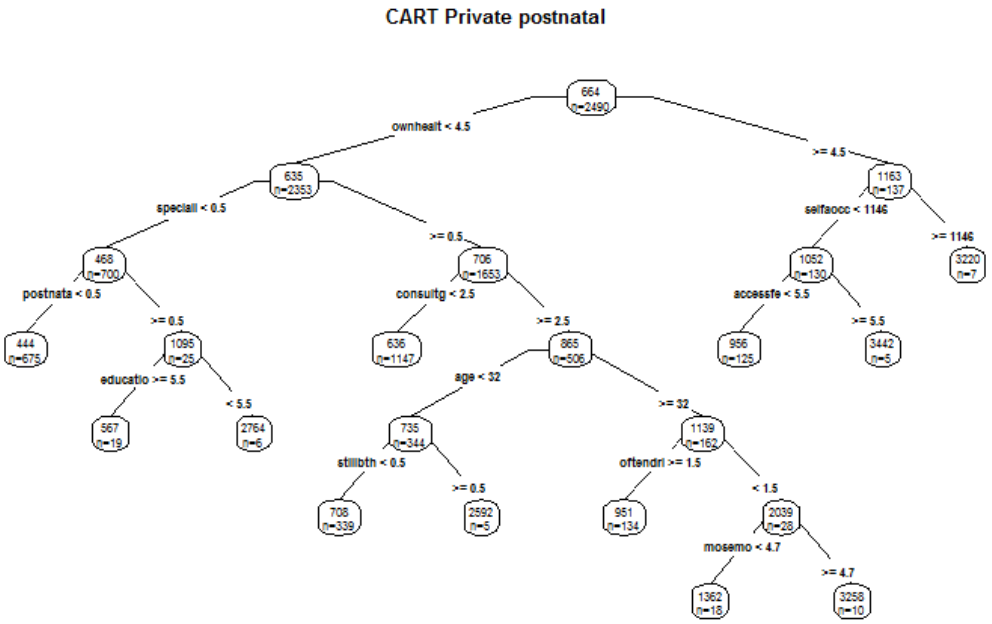
Private Delivery

Variables actually used in tree construction:
[1] breastfed
[2] electivecaesar
[3] emergencycaesar
[4] gas
[5] mostang
[6] prevlbw
[7] seifadis
[8] stillbth
[9] stress



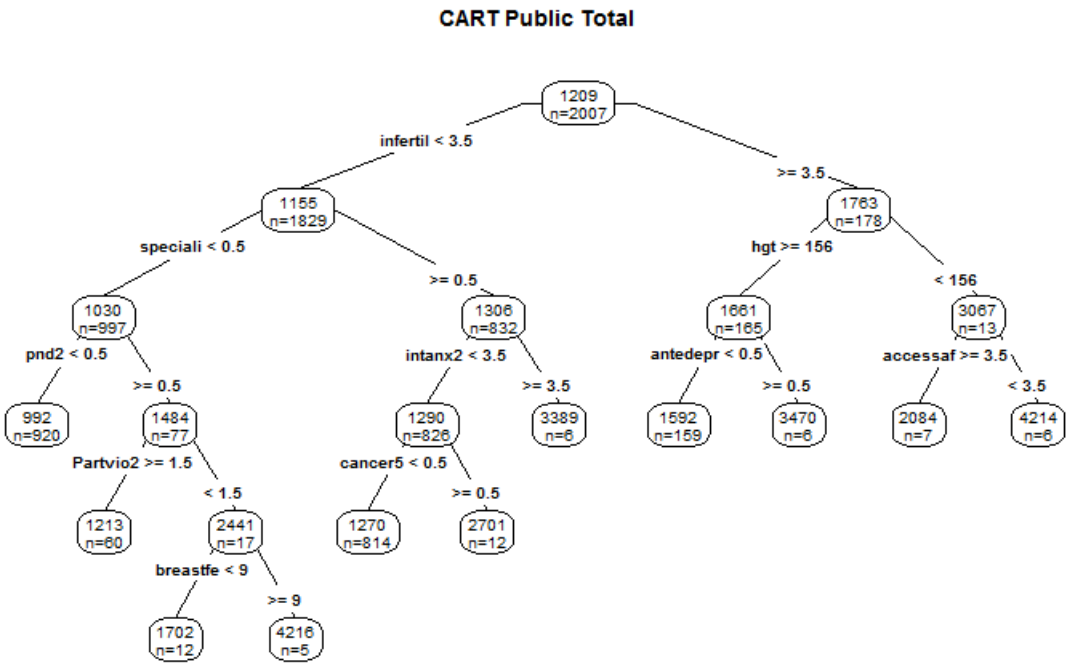
Private Postnatal

Variables actually used in tree construction:
[1] accessfemgp
[2] age
[3] consultgp2
[4] education
[5] mosemo
[6] oftendrink
[7] ownhealthstress
[8] postnatalanxiety
[9] seifaocc
[10] specialist5
[11] stillbth



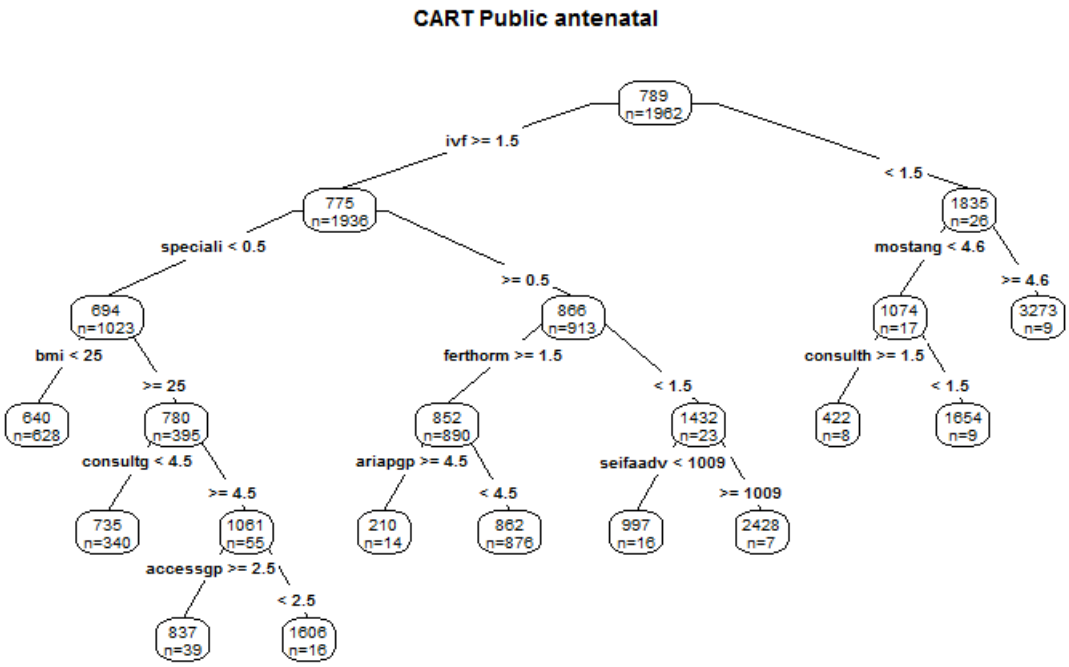
Public Total

Variables actually used in tree construction:
[1] accessafterhrsmed
[2] antedepress
[3] breastfed
[4] cancer5
[5] hgt
[6] infertility
[7] intanx2
[8] Partvio2
[9] pnd2
[10] specialist5



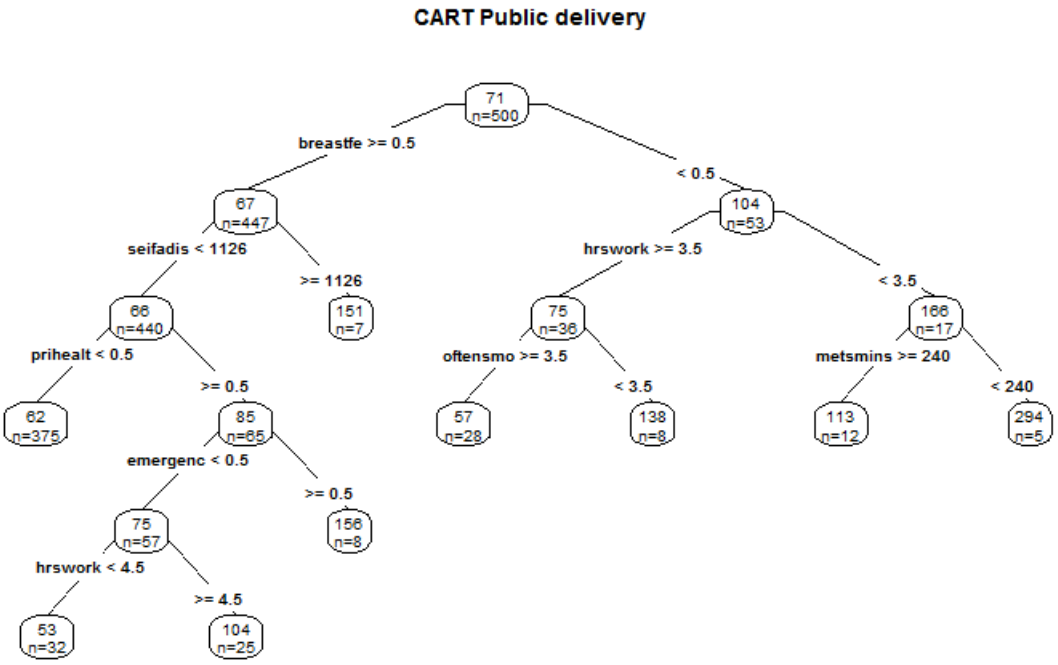
Public Antenatal

Variables actually used in tree construction:
[1] accessgpbb
[2] ariapgp
[3] bmi
[4] consultgp2
[5] consulthospdr2
[6] ferthorm
[7] ivf
[8] mostang
[9] seifaadv
[10] specialist5



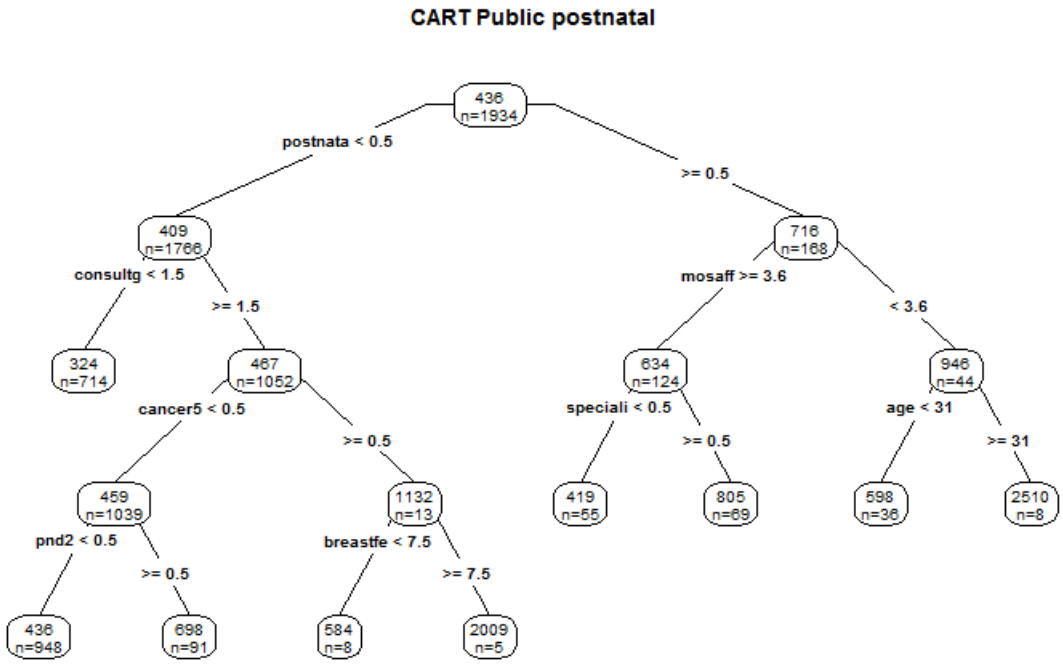
Public Delivery

Variables actually used in tree construction:
[1] breastfed
[2] emergencycaesar
[3] hrswork
[4] metsmins
[5] oftensmoke
[6] prihealthanc
[7] seifadis



Public Postnatal

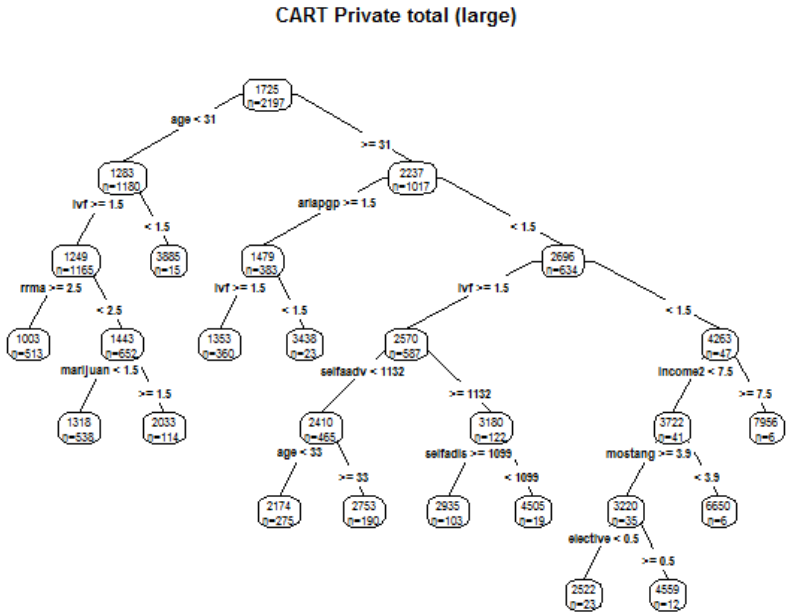
Variables actually used in tree construction:
[1] age
[2] breastfed
[3] cancer5
[4] consultgp2
[5] mosaff
[6] pnd2
[7] postnataldepress
[8] specialist5



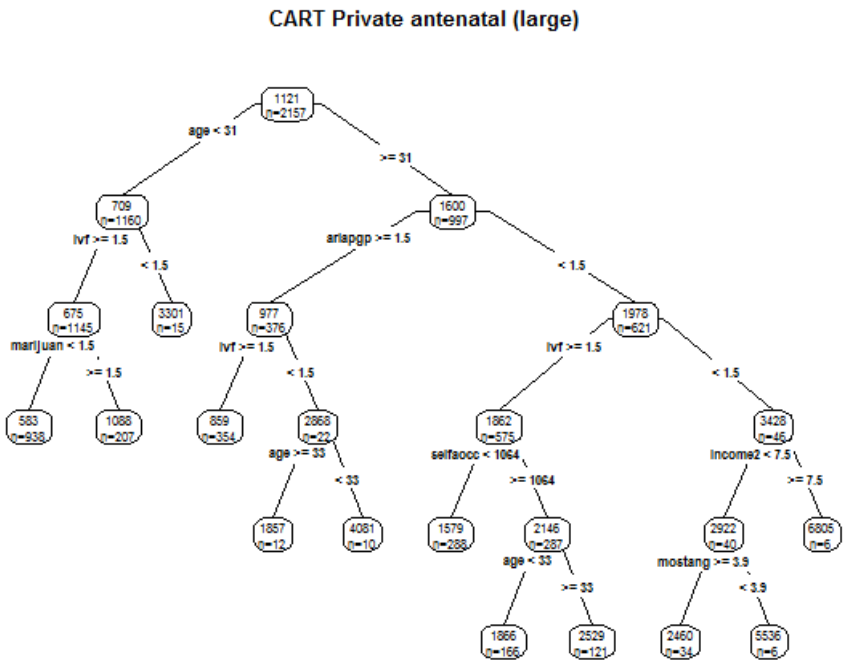
Appendix G

Selected factors for out-of-hospital costing study from CART - large

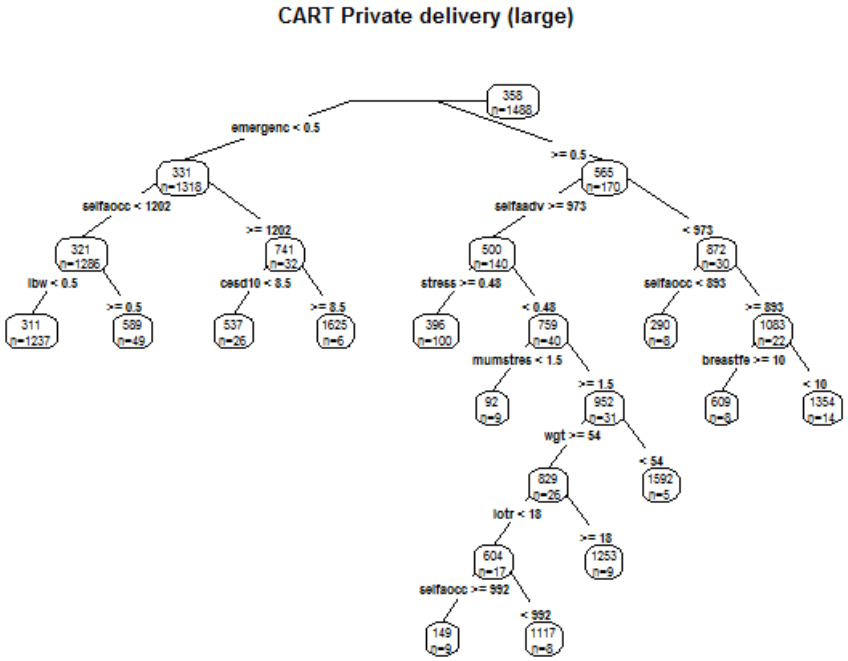
Private Total



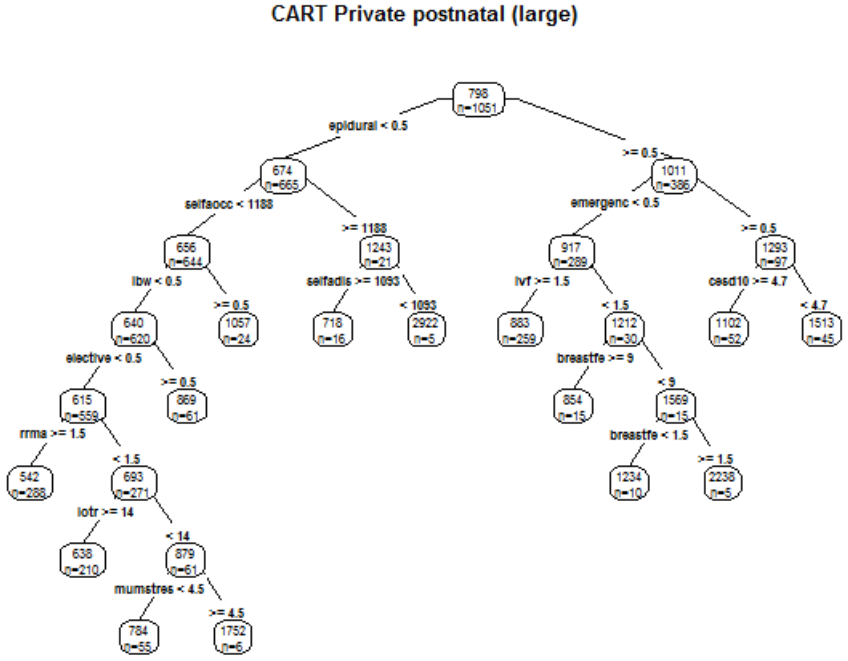
Private Antenatal



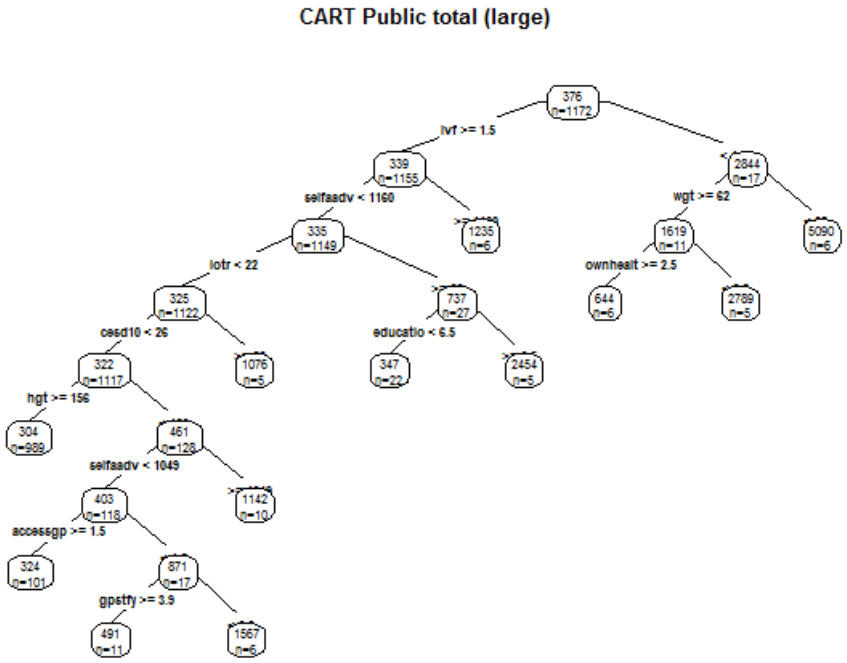
Private Delivery



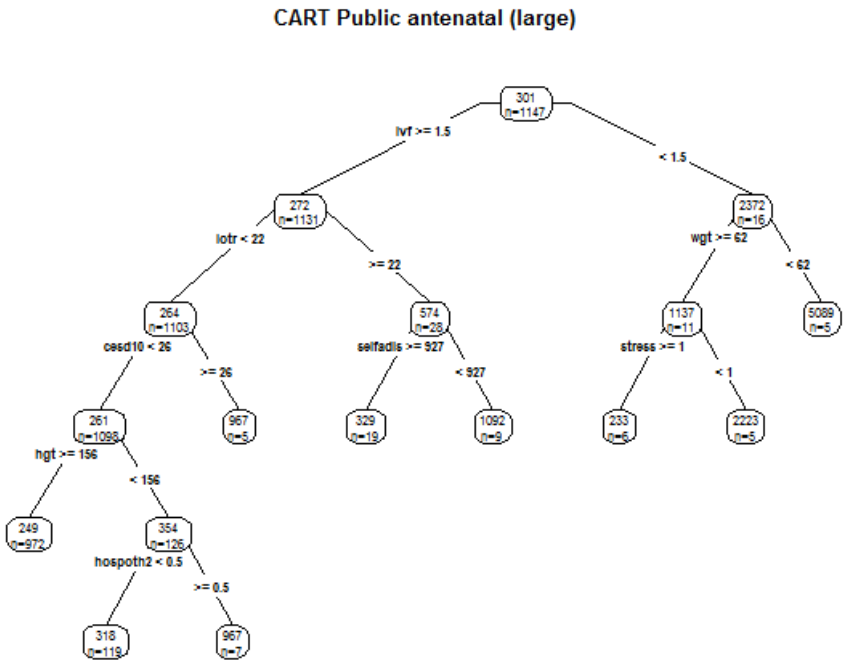
Private Postnatal



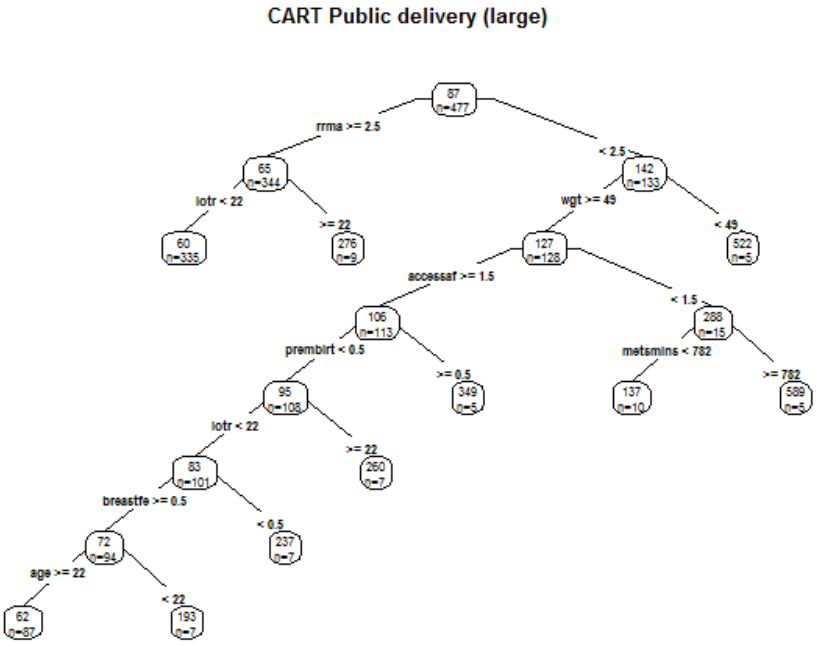
Public Total



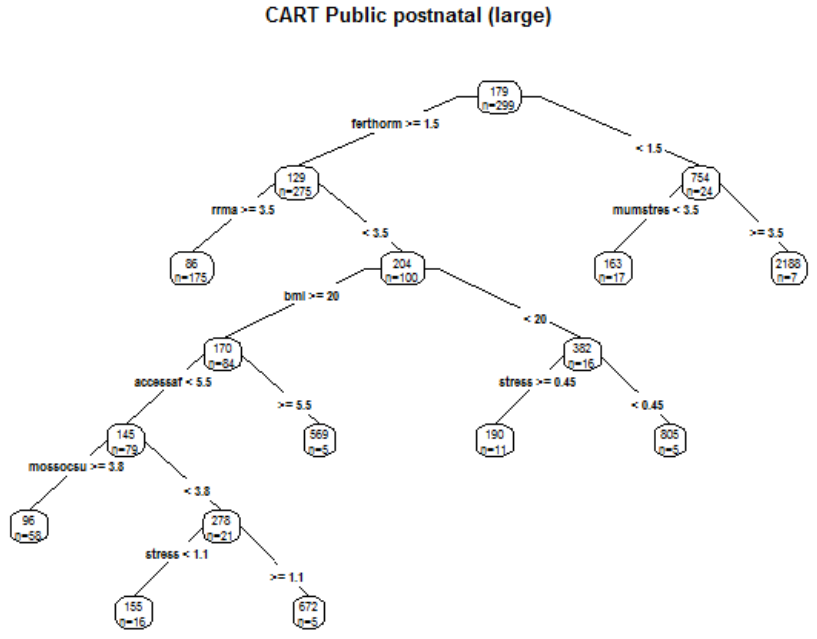
Public Antenatal



Public Delivery



Public Postnatal



Appendix H

Model refit using negative binomial distribution and backward stepwise selection for out-of-hospital costing study

Negative binomial model refit (log link, <0.01% significance) for Private Total

Coefficients	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	7.999	0.282	28.37	4.93E-177
anxiety	0.274	0.080	3.43	6.13E-04
ivf	-0.423	0.141	-3.01	2.61E-03
ownhealthstress	0.092	0.020	4.65	3.30E-06
specialist5	0.212	0.038	5.55	2.89E-08
electivecaesar	0.166	0.046	3.60	3.22E-04
type1diab	0.616	0.240	2.57	1.02E-02
ariapgp	0.217	0.155	1.40	1.62E-01
consultgp2	0.073	0.012	5.88	4.17E-09
ab	0.167	0.060	2.79	5.28E-03
ivf:ariapgp	-0.204	0.079	-2.59	9.63E-03

Backward stepwise selections for Private Total

Coefficients	Estimate	Std. Error	t value	Pr(>|t|)	Selected stepwise	Original selection
(Intercept)	8.444	0.356	23.74	8.55E-104		
consultgp2	0.058	0.012	5.32	1.22E-07	Yes	Yes
seifaadv	0.001	0.001	2.43	1.53E-02	No	No
seifadis	-0.001	0.001	-2.03	4.25E-02	No	No
age	0.013	0.007	1.76	7.93E-02	No	No
breastfed2	-0.164	0.061	-2.66	7.83E-03	No	No
ariapgp	-0.054	0.020	-2.73	6.39E-03	No	Yes
education	-0.021	0.012	-1.65	9.84E-02	No	No
specialist5	0.206	0.034	6.08	1.61E-09	Yes	Yes
hospoth2	0.125	0.051	2.46	1.42E-02	No	No
stress	0.073	0.043	1.70	8.91E-02	No	No
anxiety	0.315	0.070	4.52	6.64E-06	Yes	Yes
lotr	-0.007	0.004	-1.59	1.12E-01	No	No
occupation	-0.012	0.004	-2.81	4.97E-03	No	No
accessmed	-0.043	0.012	-3.72	2.09E-04	Yes	No
ownhealthstress	0.083	0.020	4.22	2.65E-05	Yes	Yes
cesd10	-0.011	0.004	-2.56	1.06E-02	No	No
type1diab	0.585	0.210	2.79	5.33E-03	No	Yes
electivecaesar	0.145	0.040	3.60	3.30E-04	Yes	Yes
emergencycaesar	0.119	0.043	2.74	6.26E-03	No	No
prevlbw	0.147	0.089	1.64	1.01E-01	No	No
breastfed	-0.007	0.002	-3.00	2.77E-03	No	No
ab	0.135	0.053	2.55	1.10E-02	No	Yes
antenatalanxiety	0.221	0.095	2.32	2.04E-02	No	No
Ivf	-0.696	0.067	-10.44	1.45E-24	Yes	Yes

Negative binomial model refit (log link, <0.01% significance) for Public Total

Coefficients	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	7.688	0.353	21.77	4.32E-105
cancer5	0.462	0.191	2.42	1.54E-02
consultgp2	0.092	0.015	5.95	2.63E-09
infertility	0.132	0.039	3.42	6.16E-04
postnataldepress	0.344	0.097	3.55	3.84E-04
ivf	-0.503	0.156	-3.22	1.28E-03
anxiety	1.288	0.348	3.70	2.17E-04
ariapgp	-0.095	0.025	-3.77	1.65E-04
infertility:anxiety	-0.385	0.140	-2.75	5.94E-03
(Intercept)	7.688	0.353	21.77	4.32E-105
cancer5	0.462	0.191	2.42	1.54E-02

Backward stepwise selections for Public Total

Coefficients	Estimate	Std. Error	t value	Pr(>|t|)	Selected stepwise	Original selection
(Intercept)	7.855	0.710	11.06	4.14E-26		
cancer5	0.295	0.212	1.39	1.64E-01	No	Yes
consultgp2	0.071	0.014	5.23	2.33E-07	Yes	Yes
hgt	-0.007	0.003	-2.11	3.53E-02	No	No
intanx2	0.078	0.047	1.67	9.62E-02	No	No
postnataldepress	0.341	0.082	4.18	3.40E-05	Yes	Yes
age	0.020	0.011	1.86	6.35E-02	No	No
breastfed2	-0.233	0.088	-2.66	7.98E-03	No	No
specialist5	0.079	0.045	1.77	7.72E-02	No	No
gpstfy	0.035	0.021	1.63	1.04E-01	No	No
hospoth2	0.136	0.083	1.65	9.91E-02	No	No
stress	0.160	0.048	3.31	1.00E-03	No	No
anxiety	0.213	0.115	1.85	6.46E-02	No	Yes
lotr	0.009	0.006	1.61	1.07E-01	No	No
oftendrink	-0.040	0.016	-2.47	1.38E-02	No	No
hypertension	0.195	0.087	2.24	2.53E-02	No	No
antenatalanxiety	0.380	0.147	2.59	9.75E-03	No	No
ivf	-0.459	0.140	-3.27	1.14E-03	No	Yes
infertility	0.082	0.033	2.48	1.35E-02	No	Yes

Appendix I

Public bi-monthly postnatal models

2 months

Coefficient	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	4.861	0.025	198.36	0.00000
ab	0.241	0.084	2.86	0.00426

4 months

Coefficient	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	5.113	0.095	54.12	0.000000
ariapgp	-0.082	0.026	-3.15	0.001659
ownhealthstress	0.097	0.025	3.85	0.000124
Ab	0.267	0.085	3.13	0.001753

6 months

Coefficient	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	5.292	0.096	55.03	0.00e+00
consultgp2	0.061	0.014	4.45	9.02e-06
postnataldepress	0.279	0.083	3.38	7.44e-04
ariapgp	-0.118	0.026	-4.60	4.45e-06
ownhealthstress	0.091	0.025	3.58	3.49e-04
Ab	0.260	0.085	3.06	2.24e-03

8 months

Coefficient	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	5.399	0.092	58.52	0.00e+00
consultgp2	0.075	0.013	5.70	1.38e-08
postnataldepress	0.335	0.080	4.22	2.59e-05
ariapgp	-0.118	0.025	-4.80	1.69e-06
ownhealthstress	0.114	0.024	4.67	3.20e-06
ab	0.264	0.082	3.24	1.22e-03

10 months

Coefficient	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	5.572	0.096	57.79	0.00e+00
cancer5	0.634	0.222	2.86	4.33e-03
consultgp2	0.067	0.014	4.94	8.82e-07
postnataldepress	0.408	0.083	4.93	9.08e-07
ariapgp	-0.115	0.026	-4.48	7.96e-06
hospoth2	0.263	0.092	2.87	4.17e-03
ownhealthstress	0.108	0.026	4.16	3.29e-05
ab	0.220	0.084	2.62	8.89e-03

Private bi-monthly postnatal models

2 months

Coefficient	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	5.026	0.109	45.98	0.00e+00
specialist5	0.278	0.060	4.62	4.08e-06
ownhealthstress	0.151	0.030	5.01	5.74e-07
ariapgp	-0.145	0.029	-5.03	5.42e-07
ab	0.523	0.095	5.53	3.64e-08

4 months

Coefficient	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	5.387	0.127	42.37	6.95e-284
specialist5	0.356	0.052	6.88	7.91e-12
ownhealthstress	0.197	0.026	7.56	6.02e-14
anxiety	0.373	0.120	3.10	1.99e-03
ariapgp	-0.128	0.024	-5.28	1.46e-07
breastfed2	-0.304	0.090	-3.38	7.41e-04
ab	0.417	0.084	4.98	6.81e-07

6 months

Coefficient	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	5.548	0.129	43.18	2.44e-292
consultgp2	0.065	0.017	3.92	9.22e-05
specialist5	0.357	0.052	6.81	1.29e-11
ownhealthstress	0.166	0.027	6.14	9.79e-10
anxiety	0.388	0.122	3.18	1.49e-03
ariapgp	-0.124	0.025	-5.05	4.73e-07
breastfed2	-0.330	0.090	-3.65	2.65e-04
postnataldepress	0.277	0.081	3.41	6.64e-04
ab	0.333	0.085	3.92	9.09e-05

8 months

Coefficient	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	5.708	0.121	47.19	0.00e+00
consultgp2	0.072	0.016	4.60	4.44e-06
specialist5	0.368	0.049	7.44	1.41e-13
ownhealthstress	0.159	0.026	6.23	5.66e-10
anxiety	0.439	0.115	3.80	1.48e-04
ariapgp	-0.117	0.023	-5.08	4.11e-07
breastfed2	-0.319	0.085	-3.76	1.77e-04
postnataldepress	0.277	0.077	3.62	3.07e-04
ab	0.308	0.080	3.87	1.13e-04

10 months

Coefficient	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	5.925	0.126	47.03	3.16e-322
consultgp2	0.078	0.016	4.93	9.01e-07
specialist5	0.358	0.052	6.92	6.01e-12
ownhealthstress	0.141	0.027	5.27	1.50e-07
anxiety	0.457	0.116	3.95	8.16e-05
ariapgp	-0.114	0.024	-4.76	2.08e-06
breastfed2	-0.347	0.088	-3.92	9.05e-05
endometriosis	0.300	0.108	2.78	5.53e-03
postnataldepress	0.244	0.080	3.07	2.18e-03
ab	0.236	0.083	2.84	4.55e-03

Appendix J

Frequency GLM output for out-of-hospital study – small

Private Total

Coefficient	Estimate	Std. Error	z value	Pr(>|z|)
(Intercept)	-83.634	36.459	-2.29	2.18e-02
ariapgp	48.902	15.077	3.24	1.18e-03
breastfed	-0.008	0.002	-4.66	3.11e-06
consultgp2	-29.312	11.046	-2.65	7.96e-03
electivecaesar	0.172	0.033	5.25	1.51e-07
hyperten	0.264	0.050	5.23	1.66e-07
ownhealthstress	0.067	0.015	4.41	1.05e-05
specialist5	0.164	0.028	5.94	2.86e-09
yob	0.044	0.018	2.40	1.66e-02
ivf	-0.131	0.117	-1.12	2.63e-01
type1diab	0.567	0.176	3.23	1.24e-03
cesd10	-0.011	0.004	-3.22	1.27e-03
anxgad	0.019	0.006	3.17	1.52e-03
occupation	-0.011	0.003	-3.12	1.81e-03
consultgp2:yob	0.015	0.006	2.64	8.22e-03
consultgp2:ivf	0.108	0.038	2.84	4.52e-03
ariapgp:yob	-0.024	0.008	-3.22	1.28e-03
ariapgp:ivf	-0.258	0.059	-4.34	1.40e-05

Private Antenatal

Coefficient	Estimate	Std. Error	z value	Pr(>|z|)
(Intercept)	-81.393	14.925	-5.45	4.94e-08
ariapgp	0.179	0.104	1.71	8.64e-02
consultgp2	-0.100	0.064	-1.56	1.20e-01
hyperten	0.170	0.048	3.56	3.73e-04
ivf	-0.299	0.108	-2.77	5.54e-03
ownhealthstress	0.059	0.013	4.38	1.19e-05
specialist5	0.121	0.026	4.58	4.74e-06
type1diab	0.612	0.167	3.67	2.44e-04
yob	0.042	0.007	5.70	1.20e-08
electivecaesar	0.134	0.031	4.32	1.53e-05
education	-0.026	0.009	-2.95	3.13e-03
consultgp2:ivf	0.077	0.033	2.33	1.97e-02
ariapgp:ivf	-0.154	0.053	-2.90	3.70e-03

Private Delivery

Coefficient	Estimate	Std. Error	z value	Pr(>|z|)
(Intercept)	0.588	0.0862	6.81	9.44e-12
electivecaesar	0.393	0.0664	5.92	3.30e-09
emergencycaesar	0.370	0.0705	5.25	1.50e-07
prihealthanc2	0.407	0.0887	4.59	4.44e-06
ab	0.407	0.0746	5.46	4.69e-08
hypertension	1.042	0.2585	4.03	5.53e-05
prihealthanc2:hypertension	-0.856	0.2721	-3.15	1.66e-03

Private Postnatal

Coefficient	Estimate	Std. Error	z value	Pr(>|z|)
(Intercept)	2.218	0.082	27.10	1.03e-161
breastfed2	-0.227	0.057	-3.98	6.78e-05
consultgp2	0.076	0.011	7.16	8.21e-13
emergencycaesar	0.230	0.047	4.95	7.36e-07
hyperten	0.198	0.064	3.10	1.90e-03
ownhealthstress	0.107	0.017	6.16	7.38e-10
specialist5	0.223	0.034	6.51	7.65e-11
ariapgp	-0.119	0.015	-7.96	1.68e-15
electivecaesar	0.233	0.044	5.33	1.01e-07
anxiety	0.197	0.078	2.53	1.14e-02
postnataldepress	0.183	0.052	3.53	4.10e-04
hypertension	0.186	0.057	3.27	1.08e-03

Public Total

Coefficient	Estimate	Std. Error	z value	Pr(>|z|)
(Intercept)	2.821	0.088	32.17	4.59e-227
ariapgp	-0.080	0.015	-5.20	2.04e-07
consultgp2	0.068	0.008	8.10	5.58e-16
infertility	0.089	0.020	4.39	1.15e-05
bmi	0.011	0.003	4.29	1.82e-05
accessgpbb	-0.034	0.009	-3.91	9.36e-05
prihealthanc2	0.165	0.045	3.70	2.16e-04
postnataldepress	0.257	0.051	5.01	5.35e-07
specialist5	0.115	0.030	3.88	1.06e-04

Public Antenatal

Coefficient	Estimate	Std. Error	z value	Pr(>|z|)
(Intercept)	2.821	0.0877	32.17	4.59e-227
ariapgp	-0.080	0.015	-5.20	2.04e-07
consultgp2	0.068	0.008	8.10	5.58e-16
infertility	0.089	0.020	4.39	1.15e-05
bmi	0.011	0.003	4.29	1.82e-05
accessgpbb	-0.034	0.009	-3.91	9.36e-05
prihealthanc2	0.165	0.045	3.70	2.16e-04
postnataldepress	0.257	0.051	5.01	5.35e-07
specialist5	0.115	0.030	3.88	1.06e-04

Public Delivery

Coefficient	Estimate	Std. Error	z value	Pr(>|z|)
(Intercept)	0.518	0.038	13.74	6.18e-43
hypertension	0.324	0.092	3.54	3.94e-04

Public Postnatal

Coefficient	Estimate	Std. Error	z value	Pr(>|z|)
(Intercept)	2.150	0.051	42.01	0.00e+00
consultgp2	0.082	0.011	7.85	4.25e-15
Accessgpbb	-0.058	0.011	-5.44	5.21e-08
Postnataldepress	0.355	0.062	5.76	8.47e-09
Ab	0.312	0.065	4.82	1.44e-06
specialist5	0.182	0.037	5.00	5.82e-07

Severity GLM output for out-of-hospital study – small

Private Total

Coefficient	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	4.831	0.074	65.01	0.00e+00
ariapgp	-0.096	0.008	-12.78	1.13e-35
ivf	-0.447	0.036	-12.38	1.15e-33
anxiety	0.154	0.038	4.07	4.98e-05
specialist5	0.068	0.018	3.67	2.54e-04

Private Antenatal

Coefficient	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	5.222	0.087	60.3	0.00e+00
ariapgp	-0.098	0.009	-10.7	4.66e-26
ivf	-0.618	0.043	-14.2	3.71e-43

Private Delivery

Coefficient	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	4.317	0.099	43.56	9.75e-237
accessafterhrsmed	-0.051	0.019	-2.62	9.01e-03
prihealthanc2	-0.240	0.086	-2.79	5.33e-03

Private Postnatal

Coefficient	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	3.874	0.022	177.25	0.00e+00
anxiety	0.234	0.043	5.41	7.11e-08
ariapgp	-0.077	0.008	-9.43	9.16e-21
specialist5	0.099	0.019	5.33	1.10e-07

Public Total

Coefficient	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	4.757	0.131	36.40	2.73e-173
ivf	-0.591	0.063	-9.37	6.61e-20
postnataldepress	0.152	0.041	3.71	2.24e-04
mumstress	0.035	0.010	3.44	6.18e-04

Public Antenatal

Coefficient	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	4.757	0.131	36.40	2.73e-173
ivf	-0.591	0.063	-9.37	6.61e-20
postnataldepress	0.152	0.041	3.71	2.24e-04
mumstress	0.035	0.010	3.44	6.18e-04

Public Delivery

Coefficient	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	3.698	0.041	90.45	8.75e-306
emergencycaesar	0.271	0.121	2.25	2.50e-02
ab	0.225	0.136	1.66	9.71e-02

Public Postnatal

Coefficient	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	3.760	0.022	172.43	0.000000
ariapgp	-0.037	0.010	-3.64	0.000282
postnataldepress	0.113	0.034	3.32	0.000912
anxiety	0.128	0.046	2.77	0.005656

Appendix K

Frequency GLM output for out-of-hospital study – large

Private Total

Coefficient	Estimate	Std. Error	z value	Pr(>|z|)
(Intercept)	2.275	0.036	63.71	0.000
epidural	0.137	0.014	9.52	0.000
Ab	-0.172	0.026	-6.52	0.000
ariapgp	0.016	0.019	0.85	0.395
accessmed	0.014	0.012	1.15	0.250
specialist5	0.049	0.016	3.01	0.003
ariapgp:accessmed	-0.023	0.006	-3.84	0.000

Private Antenatal

Coefficient	Estimate	Std. Error	z value	Pr(>|z|)
(Intercept)	2.378	0.023	100.48	0.00E+00
epidural	0.135	0.014	9.37	7.31E-21
ab	-0.170	0.026	-6.47	9.91E-11
ariapgp	-0.049	0.008	-5.89	3.91E-09
accessmed	-0.026	0.006	-4.23	2.36E-05
specialist5	0.047	0.016	2.91	3.61E-03

Private Delivery

Coefficient	Estimate	Std. Error	z value	Pr(>|z|)
(Intercept)	0.482	0.022	22.100	0.000
emergencycaesar	0.232	0.058	4.000	0.000

Private Postnatal

Coefficient	Estimate	Std. Error	z value	Pr(>|z|)
(Intercept)	0.808	0.026	31.01	0.000
Epidural	0.324	0.039	8.33	0.000

Public Total

Coefficient	Estimate	Std. Error	z value	Pr(>|z|)
(Intercept)	1.832	0.036	50.44	0.000
Ariapgp	0.090	0.013	6.71	0.000
Accessmed	-0.040	0.009	-4.71	0.000

Public Antenatal

Coefficient	Estimate	Std. Error	z value	Pr(>|z|)
(Intercept)	66.966	8.035	8.33	0.000
accessmed	-0.043	0.009	-4.63	0.000
ariapgp	0.074	0.014	5.10	0.000
yob	-0.033	0.004	-8.12	0.000

Public Delivery

N/A

Public Postnatal

N/A

Severity GLM output for out-of-hospital study – large

Private Total

Coefficient	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	-281.798	33.588	-8.39	1.17E-16
ariapgp	0.023	0.232	0.099	9.22E-01
ivf	-0.596	0.209	-2.86	4.37E-03
yob	0.144	0.017	8.59	2.18E-17
ab	0.258	0.093	2.79	5.34E-03
specialist5	-0.101	0.129	-0.78	4.33E-01
ariapgp:ivf	-0.168	0.114	-1.48	1.39E-01
ariapgp:specialist5	0.176	0.064	2.77	5.66E-03

Private Antenatal

Coefficient	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	-374.000	46.400	-8.06	0.000
ivf	-1.050	0.149	-7.04	0.000
yob	0.189	0.023	8.19	0.000
specialist5	0.294	0.082	3.59	0.000
seifaadv	0.001	0.000	3.55	0.000

Private Delivery

Coefficient	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	5.583	0.065	85.51	0.00E+00
emergencycaesar	0.590	0.102	5.78	9.26E-09
electivecaesar	0.265	0.092	2.87	4.16E-03
specialist5	0.208	0.074	2.80	5.19E-03

Private Postnatal

Coefficient	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	5.909	0.219	26.92	1.03E-117
emergencycaesar	0.420	0.080	5.24	1.96E-07
seifaadv	0.0005	0.0002	2.60	9.46E-03
epidural	0.266	0.054	4.89	1.19E-06
electivecaesar	0.255	0.067	3.81	1.48E-04

Public Total

Coefficient	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	10.590	0.575	18.41	6.32E-57
ivf	-1.760	0.348	-5.05	6.33E-07
ferthorm	-1.560	0.233	-6.68	6.81E-11

Public Antenatal

Coefficient	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	9.710	0.368	26.40	8.90E-93
ivf	-2.880	0.186	-15.50	2.26E-43

Public Delivery

N/A

Public Postnatal

Coefficient	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	10.028	0.895	11.20	1.26E-19
ariapgp	-0.571	0.159	-3.59	5.04E-04
ferthorm	-2.259	0.448	-5.04	1.94E-06