The Costs of Keeping Cool for Australians with Multiple Sclerosis

George Verikios, Michael P. Summers and Rex D. Simmons*

Abstract

Heat intolerance is a significant medical problem affecting people with multiple sclerosis (MS). For people with MS, the costs of running their air conditioners are an additional disease-related expense that must be met on top of other out-of-pocket disease-related expenses. Using the results of the 2008 Keeping Cool Survey, we estimate the relative economic disadvantage faced by MS households in trying to keep cool. We find that MS households spend around four times more on keeping cool than average Australian households. Sensitivity analysis indicates that our results are robust with respect to all key inputs and parameters.

1. Introduction

Multiple sclerosis (MS) is a chronic, progressive, and incurable disease that attacks the central nervous system; that is, the brain and spinal cord. There are approximately 20,000 people with MS in Australia,¹ most of whom are of working age and three-quarters are women (Access Economics 2005). Heat intolerance is a significant medical problem affecting people with MS: as little as a 0.2°C–0.5°C increase in core body temperature creates an increase in MS symptoms (Guthrie and Nelson 1995). Furthermore, ‘heat worsens and cooling improves negative symptoms of MS, sometimes dramatically so’ (Baker 2002, p. 1,779).

As a consequence of their heat intolerance, people with MS in Australia use air conditioners extensively on hot days and nights out of medical need. For people with MS, the costs of running their air conditioners are a disease-related expense that must be met on top of other disease-related expenses. All of these expenses must be met from lower-than-average incomes that people with MS earn: according to the Australian Multiple Sclerosis Longitudinal Study,² in 2007, 52 per cent of Australians with MS had annual incomes below $26,000. This compares to Australian average annual earnings of $45,000 for 2007 (ABS 2011). Higher-than-average cooling costs, combined with relatively rapidly rising electricity costs and an increasing number of hot days and nights, suggest that, over time, people with MS on low incomes face a high and rising economic disadvantage in trying to keep cool. But, what is the current degree of economic disadvantage in trying to keep cool for people with MS? This work addresses that question.
Notwithstanding the importance of keeping cool for people with MS, no previous research (that we are aware of) has explored and described the use of air conditioners by people with MS across Australia or in other countries. While studies of the economic costs of MS generally report direct (medical or non-medical) costs, indirect costs (for example, lost earnings), intangible costs (for example, psychic or welfare costs) or all three (Naci et al. 2010), they do not identify the extra cost of intensive air-conditioner use by persons with MS. To address this absence, the Keeping Cool Survey (KCS) was conducted by Summers and Simmons (2009). Overlap of respondents to the KCS and two previous economic surveys that were conducted as part of the Australian Multiple Sclerosis Longitudinal Study\(^2\) enabled analysis regarding air conditioning use by people with MS who are likely to be eligible for a concession or rebate for their electricity bills.

Using these results, we estimate the average hours of air conditioner use by people with MS in seven of the eight Australian states and territories. Applying a range of electricity prices to the use estimates and adjusting for the efficiency of air conditioners and cooling loads across regions, we estimate the average cost of running air conditioners by people with MS over the warmer months of the year. Comparing these results to similar averages for the average consumer gives an indication of the degree of economic disadvantage suffered by people with MS in their attempt to minimise the negative medical effects of heat intolerance—such estimates are also unprecedented.

2. Aspects of Multiple Sclerosis

2.1 Heat Intolerance

Heat intolerance has been known to be a significant issue for people with MS since the late 19th century. Guthrie and Nelson’s (1995) critical review of the influence of temperature changes on MS traces the scientific and medical understanding of the issue from Uhthoff’s work in 1890 to more recent work. Two key points emerge from their review: (i) internationally, MS symptoms increase in about 80 per cent of people with MS when they get too warm; and (ii) the exact physiological cause cannot be fully explained through the usual hypothesis that heat blocks the nerve conduction of already damaged (demyelinated) axons of nerve cells.

Heat is generally associated with an increase in MS symptoms, such as blurred vision, extreme fatigue, muscle weakness, pain, tremors, memory problems, loss of balance, bladder and bowel problems, numbness and tingling, decreases in cognitive function and partial, or complete paralysis (Guthrie and Nelson 1995; Simmons et al. 2001; Lerdal et al. 2007).\(^3\)

Paradoxically, while exposure to the cold is generally helpful and reduces MS symptoms (NASA/MS Cooling Study Group 2003; Petrilli et al. 2004; Meyer-Heim et al. 2007), some people with MS (5–30 per cent) have a worsening of symptoms in the cold (Visscher et al. 1983; Simmons et al. 2001).

Heat intolerance has significant quality-of-life impacts in the day-to-day lives of people with MS and their family (De Judicibus and McCabe 2007). Also, managing heat-related problems is a key component in ensuring that people with MS are able to retain employment (Johnson and Fraser 2005). These findings are reinforced by a recent survey of people with MS that found that exposure to high temperatures was one of the three most commonly cited adverse factors in relation to their MS symptoms (Simmons et al. 2001). It is generally believed that symptoms usually return to their baseline status when the body temperature returns to normal; nevertheless, Guthrie and Nelson (1995) noted that, on rare occasions, the increase in symptoms is not reversible.

2.2 Economic Impacts

There are significant economic costs associated with having MS. Access Economics (2005) found that the average annual costs in 2005 to people with MS and their family in Australia was $10,500 ($3,893 out-of-pocket and $6,593 for informal care). These costs are likely to have increased since then. These economic costs are borne by people with MS and their family across the financial spectrum. But, like other
people in the community with chronic illnesses, people with MS have lower income levels than the general community. Although 87 per cent of people with MS are of working age and most people with MS are employed when first diagnosed, 80 per cent are not employed 10 years after diagnosis (Access Economics 2005). One result of this is that 52 per cent of Australians with MS have annual incomes below $26,000, which compares to an Australian average of $45,000 for total earnings for all employees. So, although many people with MS are initially employed, ultimately most end up on government benefits. The combination of low relative incomes and high disease-related costs borne by people with MS means that concessions, such as energy rebates, are critical in providing relief from financial pressures.

2.3 Climate

Air conditioner use by people with MS in Australia is a direct response to day-to-day weather: an increase in the number of hot days and nights will increase the use of electricity by people with MS in their efforts to keep cool. One of the difficulties of examining climatic impacts on the use of air conditioners by people with MS is the wide variability of the weather across Australia. Additionally, air temperature data have limitations because moderate-to-high levels of humidity, coupled with hot days and nights, make it more difficult for people to keep cool. Summers and Simmons (2009) present data on national averages for the annual number of hot days (35°C and over) and hot nights (20°C and over) for the last 50 years: these demonstrate a clear trend towards more hot days and nights.

2.4 Air Conditioner Use in Australia

There have been several Australian reports in recent years regarding air conditioners, climate, and energy use. One of the most important is ABS (2005), which includes data on Australian air conditioner ownership and use patterns, the thermal efficiency of household dwellings and energy use. The results from ABS (2005) are reported here as a benchmark for Australian households. The most comprehensive national estimates and projections for energy use in relation to household cooling and air conditioner use are in DEWHA (2008, p. 25), which estimates that electricity for space cooling nationally represents 4 per cent of average household energy use.

2.5 Public Policy Responses Regarding the Need for Medical Cooling

There are a number of issues affecting public policy developments in relation to people with a medical need to keep cool, the most important of which is the price of electricity. Australian electricity prices have risen by 31 per cent in real terms over 1990–2008 (Dufty 2009). This trend is accelerating; for example, the Independent Pricing and Regulatory Tribunal (2009) in New South Wales (NSW) proposed price increases for 2010 of between 18.5 per cent and 21.5 per cent. The rising relative price of electricity will place further financial burdens on those with a medical need for keeping cool.

The Ministerial Council on Energy (2008, p. 3) noted the importance of community service obligations, via subsidies to energy retailers, to assist vulnerable customers. To date, six state and territory governments have responded to the need to provide assistance to people with MS (and other heat-intolerant conditions) on low incomes:

- Victoria established the Medical Cooling Concession many years ago and currently provides a discount of 17.5 per cent off electricity bills for the six warmest months of the year.

- Western Australia (WA) implemented the Thermoregulatory Dysfunction Subsidy Scheme in 2007: in 2012–13, this was an annual payment of $545.

- NSW implemented the Medical Energy Rebate in 2010: in 2012–13, the annual payment was $215.

- Queensland implemented the Medical Cooling and Heating Electricity Rebate in 2010–
11: in 2012–13, the annual payment was $230.

- South Australia (SA) introduced the Medical Cooling and Heating Concession in January 2012: in 2012–13, the annual payment was $158.

- The Australian Capital Territory (ACT) included air conditioning as part of the Life Support Rebate in July 2012, with the annual payment totalling $122.6

The Commonwealth Government has also included a payment of $140 for medically required air conditioner use as part of its carbon tax household compensation package under the Essential Medical Equipment Payment Program, beginning in July 2012.

3. The Keeping Cool Survey

In this section, we summarise the most important results from the KCS. Appendix C of Summers and Simmons (2009) should be consulted for detailed results.

3.1 Method

The KCS was sent to 3,150 people with MS in September 2008; there were 2,385 responses (76 per cent). Of these respondents, there was an overlap of 1,578 respondents (66 per cent) across the KCS and two economic surveys that were conducted in 2003 and 2007 as part of the Australian Multiple Sclerosis Longitudinal Study. For the 1,578 participants for whom economic data were available, we compared responses between the KCS and the economic surveys to determine those who would probably be ‘concession-eligible’ (those on aged pensions, disability support pensions, Department of Veterans Affairs benefits, and/or healthcare card-holders) and those who were not. We found no systematic difference in responses to the KCS between the two groups. This is a major research finding as it was expected that those who are concession-eligible would be less able to afford the ownership and operation of air conditioners and have lower rates of air conditioner ownership and use. As such, results for the whole sample are presented below.

3.2 Demographics

Over three-quarters (79 per cent) of respondents to the KCS were female. Overall, the mean age of the participants was 52 years, with a range of 25–83 years. This gender and age distribution approximates that of the Australian MS population: 74 per cent female, and prevalence rates peak between the ages of 40 and 59 (Access Economics 2005). Approximately 36 per cent of those surveyed were likely to be eligible for a concession or rebate on their electricity bills. This assumes that eligibility for any concession will include people with MS who are heat-intolerant and who have a disability pension, aged pension, are receiving benefits from Department of Veterans’ Affairs and/or have a healthcare card. Of the remainder, approximately 54 per cent will not be in receipt of one of these benefits and 10 per cent do not have a problem with heat. As a consequence of the lack of difference in KCS responses between those that are and those that are not likely to be eligible for a medical cooling concession or rebate, the results presented below can be interpreted as being equally applicable to both groups and to people with MS generally.

The proportion of survey participants in each state and territory broadly corresponds to the distribution of people with MS across regions, as judged from the membership numbers of MS societies across Australia.7 The regional distribution is similar to that of the general population.

3.3 Problems with Heat

Only 10 per cent of the survey participants stated that they did not have a problem with heat. The most common problem that people with MS experienced when they got too hot was an extreme form of fatigue, with most experiencing a general increase in their other MS symptoms, as well. Additionally, approximately half found that heat rendered them unable to participate in social activities, normal household duties and in the workforce. While
almost 10 per cent required more medication or had to visit a health professional, 3 per cent reported being hospitalised as a consequence of the impact of heat on their MS symptoms.

3.4 Air Conditioners and Their Use

The patterns of air conditioner use by people with MS are an important input to this work. Thus, we describe these patterns below in detail.

3.4.1 Ownership

Of the survey participants, 82 per cent were using air conditioners to keep cool, with a range of 80–90 per cent (except in Tasmania, where 53 per cent were using air conditioners). This is a high level of air conditioner use relative to the national population; for example, in 2008, only 67 per cent of all households nationally had an air conditioner (ABS 2008, p. 72).

3.4.2 Types of Air Conditioning

Survey responses indicated that, nationally, approximately 56 per cent of respondents used split system air conditioners, 21 per cent used ducted air conditioners, 19 per cent used evaporative air conditioners, and 14 per cent had window units. Although evaporative air conditioners are much less expensive to operate (approximately one-eighth of the cost of reverse-cycle air conditioners for ducted systems), in humid climates they are ineffective. Comparative data are available on types of air conditioners used by households across regions (ABS 2005). Figure 1 compares air conditioner types (evaporative and refrigerated or reverse cycle) between the KCS and ABS (2005). Proportions in the two surveys are similar across regions, with the exception of the ACT. To create comparable data, the KCS categories of ‘split system’ and ‘window units’ were combined to create ‘refrigerated or reverse cycle’ and ducted systems were not incorporated (as noted above, they could be either evaporative or refrigerated). So, although ownership of air conditioners is higher for people with MS, the type of air conditioners used is similar to national trends for different locations.

3.4.3 The Age of the Air Conditioner

The age of a refrigerated or reverse-cycle air conditioner is an indicator of its efficiency. At the time of the survey, an air conditioner that was more than 3 years old was very unlikely to have inverter technology, which increases cooling efficiency by 20–30 per cent. Similarly, air conditioners that are 10 or more years old are likely to be even less efficient as a consequence.
of less efficient designs and the increased likelihood of requiring maintenance and/or repairs to optimise efficiency. The national distribution of the age of refrigerated or reverse-cycle air conditioners from the survey is 36 per cent in the range of 0–3 years, 43 per cent in the range of 4–9 years, and 21 per cent for more than 10 years old.

3.4.4 The Size of the Cooled Space

Another critical element in relation to air conditioner use (and energy consumption and cost) is the size of the space being cooled. Nationally, there is an almost even distribution across three categories: 34 per cent (one room); 33 per cent (two rooms); and 33 per cent (four or more rooms). This also reflects the regional distribution, with two exceptions: WA had more ‘four or more rooms’ responses (42 per cent) and fewer ‘one room’ responses (21 per cent); Tasmania had fewer ‘four or more rooms’ responses (23 per cent) and more ‘one room’ responses (44 per cent).

3.4.5 When Is the Air Conditioner Turned On?

Most people with MS who are heat-sensitive can tell you the precise air temperature point at which their symptoms increase. But, because variability in humidity levels alters this temperature point, the survey used ranges rather than exact temperature points. Figure 2 summarises the responses.

Nationally, the average temperature at which people with MS turned on their air conditioners was 29.2°C, with many turning on their air conditioner at lower temperatures. The lowest average temperature when air conditioners were turned on was 26.4°C in Tasmania, while the highest were 30.6 and 30.2°C in SA and WA, respectively.

3.4.6 Hours of Air Conditioner Use

The final major determinant of energy use and cost in relation to keeping cool is the number of hours that people with MS operate their air conditioners. In order to keep the survey form short and maximise response rates, usage data were collected for 2-month increments. Also, although data were collected for 12 months, only the 8 months of warmer weather and air conditioner use are reported here. It is possible that some recall bias may be present in the data for this question.

Air conditioner use data that were collected by the KCS covered five ranges: 0; 1–6; 7–12; 13–18; and 19–24 hours. Without knowing the distribution of use within these ranges, we chose mid-points for each range to indicate hours of use for each respondent: 0; 3.5; 9.5; 15.5; and 21.5 hours. Given that the choice of mid-point for each range is less than ideal, we test the sensitivity of this assumption below.

Figure 2 Outside Air Temperature at Which Air Conditioners Are Turned On
Using a mid-point for each range, we are able to impute hours of use by MS household in each state and 2-month period (Figure 3).

Figure 3 illustrates the changing hours of air conditioner use across the warm months and across regions. The annual hours of use nationally for people with MS was imputed at 1,557. The apparently high levels of use in November–December (spring–summer) and March–April (autumn), relative to January–February (summer), is an indication that it does not need to be extremely hot for people with MS to require the use of air conditioning. As shown in Figure 2, more than half of KCS respondents (54 per cent) turned on their air conditioners before the external temperature reached 30°C.

Other research for Victorian households has found that the average number of hours that air conditioners are used in the ‘warmer months’ is 107 hours (Roy Morgan Research 2008, p. ix). These data were based on recall and the completion of a questionnaire, similarly to the KCS. While it is unclear exactly what is meant by ‘warmer months’ in Roy Morgan Research (2008), the imputed total for average Victorian household usage for someone with MS in the KCS was 1,508 hours over September to April. Given the similarity in methods and the similar possibility of recall bias, the difference in the results between the two surveys is striking: people with MS may have their air conditioners on almost 15 times as much as the average household.

4. Estimated Costs of Air Conditioning Use by Multiple Sclerosis Households

4.1 Base Estimates

Here, we apply the survey results to model the costs of air conditioner use by people with MS (or MS households) and compare these costs to those for the average Australian household.

4.1.1 Hours of Use

Let $USER_{prh}$ represent the number of KCS respondents indicating $h$ ($=1, …, 5$) range of hours of air conditioner usage during period $p$ ($=1, …, 4$), in region $r$ ($=1, …, 7$) and let $MID_h$ represent the mid-points for the $h$ range of hours of air conditioner usage. Imputed total hours $IMPHR_{prh}$ is then:

$$IMPHR_{prh} = USER_{prh} \times MID_h$$  \hspace{1cm} (1)

Average daily use per person in period $p$ and region $r$ $AVHR_{pr}$ is given by:

$$AVHR_{pr} = \frac{\sum_{h=1}^{5} IMPHR_{prh}}{\sum_{i=1}^{5} USER_{pri}}$$  \hspace{1cm} (2)

National average daily use per person by period $NATAVHR_p$ is given by:
To calculate annual hours of use by region and nationally requires an estimate of average daily use per person for the whole year. This will be a share-weighted average of AVHRpr and NATAVHRp, where the weights are the relative lengths of each 2-month period:

\[ \text{YRAVHR}_r = \sum_{p=1}^{4} \frac{\text{MAHR}_{pr}}{\sum_{q=1}^{4} \text{DAY}_q} \times \left( \text{DAY}_p / \sum_{q=1}^{4} \text{DAY}_q \right) \]  

\[ \text{NATYRAVHR} = \sum_{p=1}^{4} \frac{\text{NATAVHR}_p}{\sum_{q=1}^{4} \text{DAY}_q} \times \left( \text{DAY}_p / \sum_{q=1}^{4} \text{DAY}_q \right) \]  

where DAYp is the number of days in each 2-month period.

Multiplying average daily use per person by the total number of days in the four 2-month periods gives an estimate of hours of use by period \( r \) and region \( p \) \( \text{HOUR}_r pr \):

\[ \text{HOUR}_r = \text{YRAVHR}_r \times \sum_{p=1}^{4} \text{DAY}_p \quad (6) \]

\( \text{HOUR}_r pr \) is the data presented in Figure 3. Our estimate of national hours of use by period \( \text{NATHOUR}_r \) is calculated similarly to \( \text{HOUR}_r pr \):

\[ \text{NATHOUR} = \text{NATYRAVHR} \times \sum_{p=1}^{4} \text{DAY}_p \quad (7) \]

4.1.2 Efficiency

We must account for differences in the efficiency (that is, cost per hour) of air conditioners used across respondents. We do not have responses on efficiency, so we extrapolate as follows. Using data from SEA (2002), costs per hour of air conditioner use were calculated based on two price points that were adjusted for efficiency. SEA (2002) estimated costs per hour of $0.33–$0.35/hour for 1–2 star-rated air conditioners and $0.24–$0.27/hour for 4–6 star-rated units. These cost estimates were extrapolated to an average cost for each of three star ratings: 1–2 stars = $0.34; 3–4 stars = $0.2975; and 5–6 stars = $0.255 (that is, the mid-point in each range); we represent the cost per hour for each of the \( a = 1, \ldots, 3 \) star ratings as \( \text{COSTHR}_a \). The age of air conditioners (Section 3.4.3) was used as a proxy for efficiency, with 5–6 star weightings applied to those that are 3 years old or less, 3–4 stars applied for those that are 4–9 years old and 1–2 stars applied for those that are 10 or more years old. We represent the age of an air conditioner in region \( r \) with star rating \( a \) as \( \text{AGE}_{ra} \).

A weighted average cost per hour of air conditioner operation for each region \( \text{AVCOSTHR}_r \) was then calculated, taking into account variation in the age of air conditioners across states:

\[ \text{AVCOSTHR}_r = \sum_{a=1}^{3} \left( \frac{\text{AGE}_{ra}}{\sum_{b=1}^{3} \text{AGE}_{rb}} \times \text{COSTHR}_a \times \text{PRIRAT}_r \right) \frac{\text{DAY}_p}{\sum_{q=1}^{4} \text{DAY}_q} \times \sum_{p=1}^{4} \text{DAY}_p \quad (8) \]

National average cost per hour is calculated similarly:

\[ \text{NATAVCOSTHR} = \sum_{a=1}^{3} \left( \frac{\sum_{r=1}^{3} \text{AGE}_{ra}}{\sum_{b=1}^{3} \sum_{s=1}^{7} \text{AGE}_{sb}} \times \text{COSTHR}_a \times \text{NATPRIRAT} \right) \frac{\text{DAY}_p}{\sum_{q=1}^{4} \text{DAY}_q} \times \sum_{p=1}^{4} \text{DAY}_p \quad (9) \]

Our estimates of \( \text{COSTHR}_a \) are based on data from SEA (2002) that assume an electricity price of $0.15/kWh. To allow us to test the sensitivity of our results to variations in electricity prices across regions and nationally, equations (8) and (9) include the scaling factors, \( \text{PRIRAT}_r \) and \( \text{NATPRIRAT} \).

Because Victorian figures were used to estimate average costs up to this point, these were then weighted for differential cooling loads, using Victorian data as the reference point and apparent temperature as the
weighting factor. Apparent temperature is an adjustment to the ambient air temperature, based on the level of humidity: the adjustments use absolute humidity with a dew point of 14°C as the reference point (with slight adjustments depending on the temperature). If the humidity is higher than the reference point, then the apparent temperature is higher than the air temperature; if the humidity is lower than the reference point, then the apparent temperature is lower than the air temperature.

We represent apparent temperature relative to Victoria by region as $AT_r$ and nationally as $NATAT$. Our adjusted average cost per hour by region and nationally is then:

$$AVCOSTHR_r = AVCOSTHR_r \times AT_r \quad (10)$$

$$NATAVCOSTHR = NATAVCOSTHR \times NATAT \quad (11)$$

The sensitivity of the adjustment for differential cooling loads using apparent temperature is also tested below.

4.1.3 Cooling Costs

Hours of air conditioner use were then multiplied by the adjusted average cost per hour for each region:

$$COST_r = AVCOSTHR_r \times HOUR_r \quad (12)$$

$$NATCOST = NATAVCOSTHR \times NATHOUR \quad (13)$$

We calculated $COST_r$ and $NATCOST$, assuming electricity supply prices of $0.15 and $0.20/kWh, respectively, by varying $PRIRAT_r$ and $NATPRIRAT$ in equations (8) and (9). This range approximates the lower and upper bound of domestic electricity pricing across Australia in 2007: the results for $COST_r$ and $NATCOST$ are presented in Table 1.

The results show the very significant impact that as little as a $0.05 difference in price per kWh can make to overall cooling costs for MS households. This is of particular concern, given the trend of rising electricity costs and the impending introduction of smart meters and time-of-use peak pricing tariff structures in many jurisdictions.

Table 1 also provides estimates of cooling costs for all Australian households in 2007 (DEWHA 2008). In comparison to the average Australian household, the cost of keeping cool for people with MS is approximately four times higher. In Tasmania, the burden relative to average households is infinite, given that cooling costs are zero for the average Tasmanian household. In Victoria, the cost of keeping cool for people with MS is approximately
12 times higher than average; in the ACT, it is six times higher. This translates into a significant economic burden for people with MS with respect to keeping cool. Given these costs for MS households, it is all the more remarkable that there are no differences in air conditioner use between those who can most afford it (not likely to be concession-eligible) and those who can least afford it (those likely to be concession-eligible). The most probable conclusion from this is that keeping cool is a very high priority for people with MS, irrespective of their capacity to pay. That is, people with MS try to keep cool out of medical need rather than for comfort.

The estimates in Table 1 also suggest that, in general, the existing assistance schemes are not adequate to cover the extra cost of cooling that is incurred by people with MS. Only the scheme in WA, with per-person assistance of $502, approaches the extra cooling costs incurred by people with MS; the schemes in other states seem to be less than adequate for this purpose.

4.2 Sensitivity Analysis

Here, we investigate the sensitivity of the results with respect to key model parameters in order to assess the robustness of the results. Specifically, our objective is to evaluate the effects of independent uncertainties about the values of model parameters. Table 2 reports the estimated means and standard deviations for average annual costs of air conditioner use by MS households if the parameters vary symmetrically following a triangular distribution. The calculation of means and standard deviations was carried out by using the systematic sensitivity methods that are automated in the GEMPACK economic modelling software (Harrison and Pearson 1996). These methods rely on a Gaussian quadrature to select a modest number of different sets of values for the varying shocks and parameters (DeVuyst and Preckel 1997). The model is solved using each different set of parameter values and the means and standard deviations are calculated over the several different solution of the model. The calculated means and standard deviations will be good approximations of the true means and standard deviations, provided that: (i) simulation results are well approximated by a third-order polynomial in the varying shocks and parameters; (ii) varying shocks and parameters have a symmetric distribution; (iii) shocks and parameters do not both vary at once; and (iv) shocks and parameters either have a zero correlation or are perfectly correlated within a specified range that is chosen by the user (for example, ±50 per cent; Arndt and Pearson 1996).

Sensitivity analysis was undertaken for the five key parameters: (i) the number of users by hours of use, 2-month period and region $USER_{prh}$; (ii) the mid-points used to impute hours of air conditioner usage from survey responses $MID_h$; (iii) cost per hour by star rating $COSTHR_a$; (iv) electricity prices across regions $PRIRAT_r$ and nationally $NATPRIRAT$; and (v) apparent temperature across regions $AT_r$ and nationally $NATAT$.

In testing the sensitivity of each parameter, we apply the mean ($\mu$) and standard deviation ($\sigma$) to calculate the 95 per cent confidence interval, assuming each cost estimate is approximately normally distributed. This seems a reasonable assumption given that the cost estimates move approximately linearly with variations in each parameter being tested. As a further indicator of the dispersion of the probability distribution, we also calculate the coefficient of variation ($\sigma/\mu$).

The sensitivity analysis indicates that, in general, the modelling is highly robust, with the results being relatively insensitive to variations in each parameter. This is apparent from the low values for the coefficient of variation. The lowest dispersion in the probability distribution is seen for variations in the number of users of air conditioners (<2 per cent) and cost per hour by age of air conditioner (<6 per cent). A somewhat larger dispersion in probability distributions is seen for variation in electricity prices (around 8 per cent). The biggest dispersion in the probability distribution is for variations in apparent temperature relative to Victoria (around 10 per cent) and the mid-points used to impute hours of air conditioner usage from survey responses (9–12 per cent).
The largest single dispersion is the probability distribution for variations in mid-points used to impute hours of air conditioner usage in the ACT, at 11.5 per cent. This represents a very narrow confidence interval. For example, the mean annual estimated cooling cost is $296 for MS households in the ACT, with a standard deviation of $34. This gives a 95 per cent confidence interval of $286–306.

### Table 2 Sensitivity Analysis of Average Annual Cost of Air Conditioner Use by Multiple Sclerosis Households at $0.15/Kwh to Various Parameters ($)

| Region                      | Mean (μ) | Standard deviation (σ) | 95% confidence interval $^a$ | CV $^b$ |
|-----------------------------|----------|------------------------|------------------------------|---------|
| **Number of users**         |          |                        |                              |         |
| Australian Capital Territory| 296      | 5                      | 286–306                      | 0.115   |
| New South Wales             | 523      | 8                      | 507–539                      | 0.015   |
| Queensland                  | 823      | 13                     | 797–849                      | 0.016   |
| South Australia             | 584      | 9                      | 566–602                      | 0.015   |
| Tasmania                    | 293      | 5                      | 283–303                      | 0.017   |
| Victoria                    | 439      | 8                      | 423–455                      | 0.018   |
| Western Australia           | 581      | 11                     | 559–603                      | 0.019   |
| Australia                   | 520      | 4                      | 512–528                      | 0.008   |
| **Mid-points**              |          |                        |                              |         |
| Australian Capital Territory| 296      | 34                     | 228–364                      | 0.015   |
| New South Wales             | 522      | 51                     | 420–624                      | 0.098   |
| Queensland                  | 823      | 56                     | 711–935                      | 0.068   |
| South Australia             | 583      | 48                     | 487–679                      | 0.082   |
| Tasmania                    | 292      | 33                     | 226–358                      | 0.113   |
| Victoria                    | 439      | 39                     | 361–517                      | 0.089   |
| Western Australia           | 580      | 58                     | 464–696                      | 0.100   |
| Australia                   | 520      | 46                     | 428–612                      | 0.088   |
| **Cost per hour by age of air conditioner** |          |                        |                              |         |
| Australian Capital Territory| 296      | 18                     | 260–332                      | 0.061   |
| New South Wales             | 522      | 33                     | 456–588                      | 0.063   |
| Queensland                  | 823      | 56                     | 711–935                      | 0.068   |
| South Australia             | 583      | 36                     | 511–655                      | 0.062   |
| Tasmania                    | 292      | 20                     | 252–332                      | 0.068   |
| Victoria                    | 439      | 26                     | 387–491                      | 0.059   |
| Western Australia           | 580      | 37                     | 506–654                      | 0.064   |
| Australia                   | 520      | 32                     | 456–584                      | 0.062   |
| **Electricity price**       |          |                        |                              |         |
| Australian Capital Territory| 296      | 24                     | 248–344                      | 0.081   |
| New South Wales             | 522      | 43                     | 436–608                      | 0.082   |
| Queensland                  | 823      | 67                     | 689–957                      | 0.081   |
| South Australia             | 583      | 48                     | 487–679                      | 0.082   |
| Tasmania                    | 292      | 24                     | 244–340                      | 0.082   |
| Victoria                    | 439      | 36                     | 367–511                      | 0.082   |
| Western Australia           | 580      | 47                     | 486–674                      | 0.081   |
| Australia                   | 520      | 42                     | 436–604                      | 0.081   |
| **Apparent temperature**    |          |                        |                              |         |
| Australian Capital Territory| 296      | 30                     | 236–356                      | 0.101   |
| New South Wales             | 522      | 53                     | 416–628                      | 0.102   |
| Queensland                  | 823      | 84                     | 655–991                      | 0.102   |
| South Australia             | 583      | 60                     | 463–703                      | 0.103   |
| Tasmania                    | 292      | 30                     | 232–352                      | 0.103   |
| Victoria                    | 439      | 45                     | 349–529                      | 0.103   |
| Western Australia           | 580      | 59                     | 462–698                      | 0.102   |
| Australia                   | 520      | 53                     | 414–626                      | 0.102   |

Notes: (a) The confidence interval assumes that the cost estimate is approximately normally distributed (that is, approximately symmetrically distributed). Thus, the upper and lower ranges are $μ ± 2σ$.

(b) CV denotes coefficient of variation, which is $σ/μ$. 

© 2013 The University of Melbourne, Melbourne Institute of Applied Economic and Social Research
confidence interval of $228–$364. The lower bound of $228 is four times the average annual cooling costs for ACT households; this represents a large disadvantage for MS households in the ACT trying to keep cool out of medical need. The upper bound of $364 is seven times the average annual cooling costs for ACT households; this represents an even larger disadvantage for MS households in the ACT trying to keep cool. The sensitivity analysis shows no evidence that questions the results presented earlier that a significant economic burden is faced by people with MS with respect to keeping cool.

5. Conclusion

Heat intolerance is a major medical problem affecting people with MS. As little as a 0.2°C–0.5°C increase in core body temperature significantly increases MS symptoms and significantly reduces the capacity of people with MS to participate in social, household, and work activities. Consequently, the use of air conditioners is usually a necessity for people with MS and an additional disease-related expense. Such cooling expenses must be met from lower-than-average incomes that people with MS earn. Cooling costs, combined with relatively rapidly rising electricity costs and the increasing number of hot days and nights due to climate change, suggest that, over time, people with MS on low incomes face a high and rising economic disadvantage in trying to keep cool on hot days and nights.

To estimate the degree of economic disadvantage faced by Australians with MS, we apply the results of the KCS that was conducted in 2008. The survey found that 90 per cent of the 20,000 people with MS in Australia are sensitive to heat and run their air conditioners more frequently and for longer periods than most Australians. The KCS found no difference in patterns of air conditioner ownership and use across income ranges, suggesting that the income elasticity of demand for air conditioning is close to zero for people with MS.

Applying the results of the KCS, we model the costs of keeping cool for people with MS. Our estimates suggest that the average cost of running an air conditioner for people with MS in Australia is between $520 (at $0.15/kWh) and $693 (at $0.20/kWh). Furthermore, the cost is higher in hotter areas and lower in cooler areas. For 2007, the estimated average cost of cooling for all Australian households was $117–$156. This indicates that, on average, people with MS spend around four times more on keeping cool than the average Australian household. We test the sensitivity of these estimates to systematic variation in key parameters. The sensitivity analysis indicates that the modeling is highly robust, with the results being relatively insensitive to variations in all parameters.

Despite the importance of keeping cool for people with MS, no previous research (that we are aware of) has explored and described the use of air conditioners by people with MS across Australia or in other countries, let alone attempted to quantify the degree of economic disadvantage that is faced by people with MS in trying to keep cool. Thus, this work is unprecedented.

Given that more than half of Australians with MS have low incomes, the economic disadvantage that is suffered by people with MS in trying to keep cool raises the policy challenge of ensuring that community service obligations to people who are heat-intolerant are met in a way that is effective and equitable. The estimates presented here are an important input to meeting this challenge. As such, public policy responses to heat intolerance for low income households will be most effective and equitable if they are aimed broadly at the wide range of people who are heat-intolerant, such as those who are serviced through the existing concession programs in six Australian states and territories. Furthermore, our estimates of significant relative economic disadvantage being experienced by people with MS support the existence of existing concession programs. Such concessions must be set at meaningful levels and be regularly adjusted to take into account changes in relative electricity prices. Finally, our estimates also support the development and implementation of such rebates in other states and territories.

First version received February 2012; final version accepted October 2012 (Eds).
We use this term interchangeably with the term 8. That is, a household that has at least one person with MS. incidence and prevalence away from the equator). 9. Note that the estimates from SEA (2002) are based on MS moderate’. of the heat but also because the disease has a known people with MS in the Northern Territory, probably because This is most likely due to the fact that there are very few establishing schemes in other jurisdictions. 7. Results from the Northern Territory are not reported as the number of participants was too small to be meaningful. This is most likely due to the fact that there are very few people with MS in the Northern Territory, probably because of the heat but also because the disease has a known ‘latitudinal gradient’ of occurrence (that is, a greater incidence and prevalence away from the equator). 8. That is, a household that has at least one person with MS. We use this term interchangeably with the term ‘people with MS’ when making comparisons to average households. 9. Note that the estimates from SEA (2002) are based on reverse-cycle air conditioning for cooling a small-to-moderate-sized space in an average-sized house of 150 square metres (the average size of an Australian dwelling) with 2.4 metre-high ceilings and a cost of electricity of $0.15/kWh. This was appropriate because when evaporative and ducted systems are excluded, 80 per cent of the respondents were cooling moderately sized spaces of one or two rooms and 20 per cent were cooling four or more rooms. 10. Note that evaporative air conditioners were excluded from the calculation of weighted-average cost per hour of air conditioner operation for each state and territory. This is because their operating costs are minimal relative to refrigerated or reverse-cycle air conditioners. Additionally, ducted cooling was excluded because, based on the findings of Roy Morgan Research (2008), there are five times as many evaporative as refrigerated or reverse-cycle ducted systems in Victoria. So, it is likely that most of the ducted cooling systems are evaporative, with the possible exception of NSW, given its higher humidity levels in coastal areas.

References

Access Economics 2005, Acting Positively: Strategic Implications of the Economic Costs of Multiple Sclerosis in Australia, Access Economics, Canberra.

Arndt, C. and Pearson, K. 1996, ‘How to carry out systematic sensitivity analysis via Gaussian quadrature and GEMPACK’, Center for Global Trade Analysis Technical Paper no. 3, Purdue University.

Australian Bureau of Statistics 2005, Environmental Issues: People’s Views and Practices, Cat. no. 4602.0, ABS, Canberra.

Australian Bureau of Statistics 2008, Environmental Issues: Energy Use and Conservation, Cat. no. 4602.0.55.001, ABS, Canberra.

Australian Bureau of Statistics 2011, Average Weekly Earnings, Australia, Cat. no. 6302.0, ABS, Canberra.

Baker, D. G. 2002, ‘Multiple sclerosis and thermoregulatory dysfunction’, Journal of Applied Physiology, vol. 92, pp. 1,779–80.

De Judicibus, M. A. and McCabe, M. P. 2007, ‘The impact of financial costs of multiple sclerosis on quality of life’, International Journal of Behavioral Medicine, vol. 14, pp. 3–11.

Department of the Environment, Water, Heritage and the Arts 2008, Energy Use in the Australian Residential Sector 1986–2020, DEWHA, Canberra.

DeVuyst, E. A. and Preckel, P. V. 1997, ‘Sensitivity analysis revisited: A quadrature-based approach’, Journal of Policy Modelling, vol. 19, pp. 175–85.

Dufty, G. 2009, ‘EWOV—Hardship: Where are we on the journey? Cost trends for essential items—Implications for Victorian households’, St Vincent de Paul Society, Melbourne.

Guthrie, C. T. and Nelson, D. A. 1995, ‘Influence of temperature changes on multiple sclerosis: Critical review of mechanisms and research potential’, Journal of the Neurological Sciences, vol. 129, pp. 1–8.

Harrison, W. J. and Pearson, K. R. 1996, ‘Computing solutions for large general equilibrium models using GEMPACK’, Computational Economics, vol. 9, pp. 83–127.

Henke, A. F., Cohle, S. D. and Cottingham, S. L. 2000, ‘Fatal hyperthermia secondary to sunbathing in a patient with multiple

© 2013 The University of Melbourne, Melbourne Institute of Applied Economic and Social Research
sclerosis’, *American Journal of Forensic Medicine and Pathology*, vol. 21, pp. 204–6. Independent Pricing and Regulatory Tribunal 2009, *Market-Based Electricity Purchase Cost Allowance—2009 Review: Regulated Electricity Retail Tariffs and Charges for Small Customers 2007 to 2010: Electricity—Draft Report*, IPART NSW, Sydney.

Johnson, K. L. and Fraser, R. T. 2005, ‘Mitigating the impact of multiple sclerosis on employment’, *Physical Medicine and Rehabilitation Clinics of North America*, vol. 16, pp. 571–82.

Kohlmeier, R. E., DiMaio, V. J. M. and Kagan-Hallet, K. 2000, ‘Fatal hyperthermia in hot baths in individuals with multiple sclerosis’, *American Journal of Forensic Medicine and Pathology*, vol. 21, pp. 201–3.

Lerdal, A., Gulowsen Celius, E., Krupp, L. and Dahl, A. A. 2007, ‘A prospective study of patterns of fatigue in multiple sclerosis’, *European Journal of Neurology*, vol. 14, pp. 1338–43.

Meyer-Heim, A., Rothmaier, M., Weder, M., Kool, J., Schenk, P. and Kesselring, J. 2007, ‘Advanced lightweight cooling-garment technology: Functional improvements in thermosensitive patients with multiple sclerosis’, *Multiple Sclerosis*, vol. 13, pp. 232–7.

Ministerial Council on Energy 2008, *Energy Community Service Obligations: National Framework*, viewed May 2009, <http://www.ret.gov.au/Documents/mce_/documents/MCE%5FEnergy%5FCommunity%5FServices%5FObligation20080929151353.pdf>.

Naci, H., Fleurence, R., Birt, J. and Duhig, A. 2010, ‘Economic burden of multiple sclerosis: A systematic review of the literature’, *PharmacoEconomics*, vol. 28, pp. 363–79.

NASA/MS Cooling Study Group 2003, ‘A randomized controlled study of the acute and chronic effects of cooling therapy for MS’, *Neurology*, vol. 60, pp. 1,955–60.

Petrilli, S., Durufle, A., Nicolas, B., Robineau, S., Kerdoncuff, V., LeTallec, H., Lassalle, A. and Gallien, P. 2004, ‘Influence of temperature changes on clinical symptoms in multiple sclerosis, an epidemiologic study’, *Annales de Réadaptation et de Médicine Physique*, vol. 47, pp. 204–8; (in French).

Roy Morgan Research 2008, *Victorian Utility Consumption Household Survey 2007*, RMR, Melbourne.

Simmons, R. D., Ponsonby, A. L., van der Mei, I. A. F. and Sheridan, P. 2001, ‘What affects your MS? Response to an anonymous, Internet-based epidemiological survey’, *Multiple Sclerosis*, vol. 10, pp. 202–11.

Summers, M. and Simmons, R. 2009, *Keeping Cool Survey: Air Conditioner Use by Australians with MS*, MS Australia, Melbourne, viewed June 2011, <http://msociety.org.au/documents/keeping-cool/MSAustralia_Keeping_Cool_Survey_Policy_Implications_Report_2009%203rd%20ed 2012.pdf>.

Sustainable Energy Authority 2002, *Operating Costs of Electrical Appliances*, June, SEA, Melbourne.

Visscher, B. R., Detels, R., Clark, V. A., Malmgren, R., Dudley, J. P. and Valdiviezo, N. L. 1983, ‘Role of heat in multiple sclerosis symptoms in a high- and a low-prevalence area’, *Neuroepidemiology*, vol. 2, pp. 56–61.