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Duration and Persistence in Multidimensional Deprivation: Methodology and Australian Application*

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Abstract:

This paper extends the recent literature on static multidimensional deprivation to propose dynamic deprivation measures that incorporate both the persistence and duration of deprivation across multiple dimensions. The paper then illustrates the usefulness of the extension by applying it to Australian panel data for the recent period, 2001-2008. The empirical application exploits the subgroup decomposability of the deprivation measures to identify the subgroups that are more deprived than others. The proposed measure is also decomposable by dimensions and is used to identify the dimensions where deprivation is more persistent. The comparison between the subgroups shows that the divide between homeowners and non-homeowners is one of the sharpest, with the latter suffering much more deprivation than the former. The results are robust to alternative schemes for weighting and aggregating the dimensions as well as to the choice of model parameters.

Keywords: Multidimensional Deprivation; Social Exclusion; Duration of Deprivation; Deprivation Persistence; Subgroup Decomposability.

JEL classification: I10, I31, I32, I38, J18

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1. INTRODUCTION

Largely inspired by the work of Sen (1985, 1992), there has been a change in our approach to welfare comparisons between individuals and between nations at any given point in time. Backed up by greater availability of data, Sen's introduction of concepts such as "functioning" and "capabilities" has led to a move away from an exclusive reliance on unidimensional and money metric measures, such as inequality and poverty rates, to multidimensional measures of deprivation based on a wider array of attributes that are more directly representative of an individual's welfare. These measures combine qualitative and quantitative information in evaluating an individual's ability to lead a decent life through access to resources that are both monetary and non-monetary in nature.

Sen's work led to the use by the United Nations Development Program [UNDP (1990)] of the Human Development Index (HDI) and the Human Poverty Index (HPI) [Bourguignon and Chakravarty (2003), Chakravarty and Majumder (2005)] that combines per capita income with life expectancy and literacy in measuring a country's average achievement. A limitation of the HDI/HPI framework has been that it ignores the distribution of deprivation between individuals. This has been addressed via the introduction of alternative multidimensional measures of deprivation in several recent contributions that take the individual, rather than the country, as the unit of analysis. These measures are based on the number of dimensions that an individual is deprived in and then aggregating the individual level information into an overall measure of multidimensional deprivation. Examples include Bourguignon and Chakravarty (2003), Chakravarty and D'Ambrosio (2006), Bossert, Chakravarty and D'Ambrosio (2009), Alkire and Foster (2010) and Jayaraj and Subramnian (2010).

Since multidimensional deprivation measures need individual level data, their informational requirements are much greater than those of the earlier aggregated measures, such as HDI, which were based on national averages. The trade-off is that the recent measures are more policy friendly in allowing the identification of population subgroups that are the prime contributors to deprivation and that need to be targeted in policy interventions.

A key limitation of the multidimensional deprivation literature has been the static nature of the measures which do not distinguish between transitory and permanent deprivation in particular dimensions. The need to make such a distinction has been emphasised by Foster (2007a) in his study of "chronic poverty" in Argentina when he asserts that "a main premise of chronic poverty is that poverty repeated over time has a greater impact than poverty that does not recur (p.7)". While the availability of panel data provided an impetus for the introduction of dynamic considerations in the literature on deprivation, such extensions are restricted to the unidimensional context.[1] Examples of recent contributions include Calvo and Dercon (2007), Foster (2007a), Bossert, Chakravarty and d'Ambrosio (2010) and Gradin, del Rio and Canto (2010). There has been no similar attempt to introduce dynamic considerations in the multidimensional context. The chief motivation of this study is to address this limitation. This paper proposes dynamic extensions of some recent multidimensional deprivation measures and applies them to study deprivation in Australia using panel data.

In incorporating dynamic considerations, this paper draws a distinction between persistence and duration of deprivation. While 'persistence' of deprivation denotes the number of uninterrupted spells of deprivation, 'duration' denotes the total number of periods of deprivation i.e., including both interrupted and uninterrupted spells.[2] The Australian application illustrates the usefulness of the dynamic extension. The proposed methodology allows for the identification of population subgroups and deprivation dimensions that are characterised by recurring and persistent deprivation so that they can be directly targeted in policy intervention.

The need to consider multiple dimensions in measuring deprivation and evaluating welfare led to several country studies that use a wide array of deprivation indicators; examples include Majumdar and Subramanian (2001) on India, Klasen (2000) on South Africa, and Hicks (1997) on a set of 20 developing countries. The empirical literature of multidimensional deprivation is not restricted to developing countries; see, for example, Chakravarty and D'Ambrosio (2006)'s study on member states of the EU, Levitas, et al (2007) on UK, Headey (2006), Saunders, et al (2007) and Scutella, et al (2009) on Australia and Ayala et al (2011) on Spanish data. The present study on Australian data is in this recent tradition and adds to the literature on multidimensional deprivation in the context of developed countries.

The Australian literature on deprivation has been both static and largely unidimensional, consisting almost entirely of inequality calculations and of poverty measurement based on the Henderson poverty line that is periodically updated by the Melbourne Institute of Applied

[1] We thank a referee for bringing the literature on dynamic unidimensional measures to our attention.

[2] See Bossert, Chakravarty and d'Ambrosio (2010) for a similar distinction in the unidimensional context.

Economic and Social Research.[3] There have recently been a few Australian studies, including the ones mentioned above, that take a wider view of deprivation than the traditional unidimensional poverty literature. These studies were made possible by the HILDA panel data set that provides unit record information on a wide range of dimensions. For example, Headey (2006), while restricting his study to poverty measurement, takes a wider view of poverty by taking account of household consumption and wealth. However, the panel nature of the HILDA data has not been fully exploited due to the adoption of a static framework in these studies. This paper moves beyond Headey's (2006) framework by considering non-monetary indicators of deprivation and then aggregating them using an axiomatic framework within the context of persistence and duration-augmented multidimensional deprivation.

The plan of the paper is as follows. Section 2 introduces the dynamic extension of the axiomatic approach to multidimensional deprivation. The data set is described in Section 3. The results are presented and analysed in Section 4. Section 5 concludes.

2. ANALYTICAL FRAMEWORK

Chakravarty and D'Ambrosio (2006) (henceforth CD), using an axiomatic framework, propose a class of multidimensional deprivation measures that are population subgroup decomposable. Several other recent papers have also proposed multidimensional measures based on an axiomatic framework [see, for example, Bossert, D'Ambrosio and Peragine (2007)]. The CD framework is adopted here since subgroup decomposability allows different population groups within Australia to be compared and analysed. Additionally, the specific forms of the measure suggested in CD allow flexibility in terms of additional properties that may be useful for different policy questions. The proceeding subsections will present a new generalisation of the class of measures used in CD and Jayaraj & Subramanian (2010) (henceforth JS) where we explicitly take into account the duration and persistence of deprivation.

2.1: The Multidimensional Deprivation Index

Assume we observe, for all N individuals in the population of interest, K different dimensions of deprivation and T equally-spaced periods of time. We say that an individual i is deprived in dimension j at time t when $x_{ijt} < h_j$, where $i \in \{1,2,\ldots,N\}$, $j \in \{1,2,\ldots,K\}, t \in$

[3] See, for example, Saunders and Bradbury (2006).

$\{1,2,\dots,T\}$, x_{ijt} is individual i's attribute level in dimension *j* at time *t*, and w_j is a cut-off point that determines whether or not an individual is considered deprived in a particular dimension. For example, in the dimension 'health', x may be the individual's Body Mass Index, in which case w would be some threshold below which the individual would be considered underweight and therefore deprived in the health dimension. Deprivation in itself need not be classified as a dichotomous outcome; i.e. either deprived or not deprived. A general specification discussed in Atkinson (2003) and applied in Alkire and Foster (2010) allows the *depth* of deprivation in a particular dimension/period to be taken into account:

$$d_{ijt}^{\gamma} = \begin{cases} \left(1 - \frac{x_{ijt}}{h_j}\right)^{\gamma} & \text{if } x_{ijt} < h_j \\ 0 & \text{otherwise} \end{cases} \tag{1}$$

where $\gamma \geq 0$ is a sensitivity parameter along the lines of the poverty measure due to Foster, Greer and Thorbecke (1984). γ allows the individual weight given to a dimension to increase with the depth of deprivation in that particular dimension. However, the types of variables used in multidimensional studies often come from survey questions that are either qualitative and/or dichotomous in nature (for example, whether an individual has access to a certain good or service or not). In such cases, deprivation has to be represented by a restriction on (1), namely, by specifying $\gamma = 0$. In other words, d_{ijt}^{0}=1 when an individual is deprived in dimension *j* at time *t* and d_{ijt}^{0}=0, otherwise.[4]

Given this, each individual i can be said to have an *individual deprivation profile*, which is a matrix $\boldsymbol{D_i} = \begin{pmatrix} d_{\boldsymbol{i}11}^{0} & \dots & d_{\boldsymbol{i}1T}^{0} \\ . & \dots & . \\ d_{\boldsymbol{i}K1}^{0} & \dots & d_{\boldsymbol{i}KT}^{0} \end{pmatrix}$ where $d_{ijt} \in \{0,1\}\ \forall j \in \{1,2,\dots,K\}$, $t \in \{1,2,\dots,T\}$ and $i \in \{1,2,\dots,N\}$. The *individual deprivation score* μ_i is a function $f\colon \boldsymbol{D_i} \to \boldsymbol{R}$ where $\boldsymbol{R}$ is the set of real numbers.[5]

The *population deprivation profile* is a vector $\boldsymbol{\rho} = (\mu_1, \dots, \mu_N)$ of individual scores in non-decreasing order. The *multidimensional deprivation index* Ω is then a function $g\colon \boldsymbol{\rho} \to \boldsymbol{R}$.

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[4] As in JS and CD, this means that properties focusing on the depth of deprivation in a particular dimension as discussed in Bourguignon and Chakravarty (2003) will not be satisfied in the measures we adopt here. Instead, we emphasise the desirable properties across (as opposed to within) dimensions, as well as across time.

[5] Given that μ_i takes as its input the (TxK) matrix $\boldsymbol{D_i}$, there can in principle be a maximum of $2^{(T*K)}$ different types of individual scores, one for each possible permutation of the individual deprivation profile.

2.2: Desirable Properties

[i] **Subgroup Decomposability (SD)**

The class of population subgroup decomposable measures requires that for any partitioning of the population, the overall index must be a population share weighted average of the subgroup indices.

[ii] **Normalisation (NN)**

Normalisation requires that Ω∈[0,1] with 1 being the maximum deprivation possible, and 0 being no deprivation.

Properties [i] and [ii] allow comparability of the measure across different populations with different numbers of deprivation dimensions and/or time periods. **SD** can be satisfied by a simple sum of individual scores. For **NN** to be satisfied while preserving **SD**, each individual score is divided by the maximum possible score, μ_{max} and the sum of these individual score ratios are further divided by N.

$$\Omega = \frac{\sum_{\mathrm{i}=1}^{\mathrm{N}} \frac{\mu_i}{\mu_{max}}}{\mathrm{N}} \qquad (2)$$

Equation (2) satisfies both **SD** and **NN**. This gives Ω a useful interpretation as the average individual deprivation score ratio in the population of interest.

[iii] **Dimensional Monotonicity (KM)**

This requires that for any time t and any individual i, Ω increases as the number of dimensions in which individual i is deprived in increases.

[iv] **Durational Monotonicity (TM)**

This requires that for any dimension j and any individual i, Ω increases as the number of periods in which individual i is deprived in increases.

Properties [iii] and [iv] can be satisfied by initially adopting a simple 'counting' approach to μ_i; that is, the input into the function f is simply the count of individual i's deprivations, $\sum_j^K \sum_t^T d_{ijt}^0$. Note the counting approach renders the measure unable to discriminate between different sources of deprivation since it is only the number of deprivations and not the dimension from which deprivation comes from that count towards the score. If there is reason to believe that certain dimensions are more important than others, relative weights can be applied to them. Atkinson (2003) notes that weights on dimensions should ideally be proportional; however, he also recognises that weights may be different if different variables are more relevant to different subsets of the population. This issue is further pursued in the discussion of the empirical application in Section 3. An additional concern that arises from the lack of identification of particular dimensions is that even when there is reason to believe that all dimensions carry equal weight, certain specific combinations of them may lead to more severe cases of deprivation. For example, numerous individuals may consider being unemployed and being unhealthy a superior state to being unemployed and being poor. These specific interactions among dimensions, if known a priori, can be incorporated into the current measure by considering not just different combinations of the elements of $\boldsymbol{D_i}$, but also different permutations. While this is beyond the scope of the present study, an interesting avenue for future research would be the development of a framework for empirically identifying interactions among dimensions in terms of their contribution towards overall deprivation.

Using the counting approach, equation (2) can be written in functional form as:

$$\Omega_\alpha = \frac{\sum_{\mathrm{i}=1}^{\mathrm{N}} \left(\frac{\sum_j^K \sum_t^T d_{ijt}^0}{T * K} \right)^\alpha}{\mathrm{N}} \qquad (3)$$

$\alpha \geq 0$ allows for the sensitivity of the aggregate index to the distribution of deprivations among individuals, in this case across time and dimensions. It is analogously applied in the unidimensional poverty context by Gradin et al (2010). When $\alpha = 0$, equation (3) gives us the headcount ratio of individuals in the population deprived in at least one dimension j for at least one time period t. When $\alpha = 1$, the weight for each individual is increasing in a linear fashion as the count of deprivations increases. As $\alpha \rightarrow \infty$, the index gives us a headcount ratio of individuals in the population deprived in all dimensions for all time periods. Following Atkinson's (2003) discussion of counting approaches to multidimensional deprivation, note that $\alpha > 1$ also implies that the cross-derivative of μ_i with respect to any two different dimensions is positive, implying that the deprivations themselves are complements in the deprivation function, while $0 < \alpha < 1$ implies they are substitutes.

Equation (3) can be seen as a generalisation of both JS and CD. In JS, the two time periods 1992-93 and 2005-06 were considered separately; therefore Ω_α was calculated with $T = 1$ and a different Ω_α provided for each time period. Although by observing the measure $\left(\Omega_\alpha|_{t=(1992-93)}\right) > \left(\Omega_\alpha|_{t=(2005-06)}\right)$ one can conclude that deprivation has been reduced over time, it becomes problematic to compare subgroups within the population over the period in question. This is because in some periods one subgroup may do better than the other, but the reverse may be true for other periods, in which case it no longer becomes clear how to conclude if one group is doing better than the other over the whole period. Equation (3), taking into account the full length of time over which one is interested in, is able to produce a single conclusive index for subgroup comparison.

CD was able, to some extent, to circumvent the issue of subgroup comparison over time. They use EU data over six years of observation (1994-99). By defining (d_{ijt}^{0}=1) as deprivation in a particular dimension j for *at least 4 out of 6* years, they are able to directly compare subgroups. However, it is not clear why at least 4 out of 6 years constitutes an interesting definition. This would exclude all individuals, who, for example, have been extremely unhealthy in the health dimension for 3 years, or who have been unemployed for 3 years. Given that one has data on the dimensions for every year, why limit what the data can tell us? Additionally, from a policy perspective, it would be useful to differentiate and identify short-term versus long-term deprivation. Also, property **TM** is not satisfied by their aggregation in terms of each individual *t*, since their measure discriminates neither between being deprived in say, 4, 5, or 6 years, nor between those deprived in 1, 2, or 3 years.

The duration-augmented measure proposed in (3) can be seen as a multidimensional analogue to Foster's (2007a) "duration-adjusted P_α measure" in the unidimensional context, which adjusts the standard headcount ratio of poverty by the average periods of poverty experienced by the individual.

2.3: Additional Properties

When $\alpha > 1$ in equation (3), two additional properties emerge[6]:

[v] **Dimensional Transfer Principle (KT)**

Assume that there are two individuals a and b where for some individual deprivation function $: \boldsymbol{D_i} \rightarrow \boldsymbol{R}$, $\mu_a > \mu_b$. If individual a suffers one additional dimension of deprivation but individual b's deprivation is reduced by one dimension, the aggregate measure must register an overall increase in deprivation.

[6] Formal definitions of the following axioms are found in Appendix B.

[vi] **Durational Transfer Principle (TT)**

Assume that there are two individuals a and b where for some individual deprivation function $: \boldsymbol{D_i} \rightarrow \boldsymbol{R}$, $\mu_a > \mu_b$. If individual a suffers one additional period of deprivation but individual b's deprivation is reduced by one period, the aggregate measure must register an overall increase in deprivation.

Both properties **KT** and **TT** are analogous to the *Pigou-Dalton transfer principle* in the context of income transfers [see, for example, Shorrocks and Foster (1987)]. Both properties are desirable since they essentially give increasingly larger weights to individuals with additional deprivations. This means that policy makers that seek to reduce deprivation [as measured by the deprivation index in (3)] would do so by first reducing the deprivation of individuals who have multiple counts of deprivation. When $\alpha > 2$ *transfer sensitivity* axioms along the lines of Shorrocks and Foster (1987) are satisfied. We define these in the Appendix B.

The measures used in JS and CD satisfy **KM,** and when $\alpha > 1$ in their measures, **KT** is satisfied as well. However, our generalised measure satisfies the additional properties of **TM,** as well as **TT** when $\alpha > 1$. When comparing subgroups of a population over a period of time, this measure has the advantage of giving increasing importance not only to those who experience a wider variation of deprivations, but also those who have experienced them for longer periods of time.

2.4: Incorporating Persistence

As a referee points out, while equation (3) may incorporate the *duration* of deprivation (that is, the count of periods in which an individual is deprived in a particular dimension), it does not explicitly consider *persistence*, that is, the deprivation of an individual in a particular dimension over *consecutive* periods. Bossert, Chakravarty and D'Ambrosio (2010) consider, in the unidimensional poverty context, a measure in which an individual who is poor in consecutive periods is given more weight relative to another who even though is deprived for the same total number of periods, moves in and out of a state of poverty. As they say, "the negative effects of a two-period spell are much harder to handle than two one-period spells that are interrupted by one (or more) period(s) out of poverty". This may not always be true in the multidimensional case. One can, for example, imagine that being unemployed for three consecutive periods and then being employed for three consecutive periods is superior to alternating in and out of employment for six periods since one incurs an 'adjustment cost' when changing states. However, information on the level of persistence is useful in many situations and, given our emphasis on the dynamics of deprivation, we specify a measure that further generalises equation (3).

Each d_{ijt}^{0} can be said to belong to a deprivation spell, which is a sequence of uninterrupted deprivation periods in a particular dimension. c_{ijt} is the *length* of the deprivation spell associated with a particular d_{ijt}^{0}.

$$\mathrm{P}\Omega_{\alpha} = \frac{\sum_{\mathrm{i}=1}^{\mathrm{N}} \left(\frac{\sum_{j}^{K} \left(\sum_{t}^{T} \left[d_{ijt}^{0} * s \right] \right)}{T * K} \right)^{\alpha}}{\mathrm{N}} \tag{4}$$

where $s \in [0,1]$ is a non-negative increasing function of c_{ijt} that takes on the maximum value of 1 when the deprivation in question ($d_{ijt}^{0} = 1$) is part of a c=T period spell.[7] Equation (4) incorporates into a multidimensional framework Gradin et al's (2010) unidimensional generalisation of persistence weights. This allows the multidimensional index to satisfy the following property while retaining properties [i]-[vi].

[vii] **Durational Persistence Monotonicity (TPM)**

This requires that for any individual i, dimension j and period t, Ω increases as c_{ijt} increases.

Choosing a functional form for s means explicitly defining an aggregate trade-off between one additional dimension of deprivation against being deprived for an additional consecutive period. Following Gradin et al (2010) and extending their idea to the multidimensional context, we specify $s = \left(c_{ijt} / T \right)^{\beta}$ where $\beta \geq 0$ is a parameter that determines the sensitivity of the index to the length of individual deprivation spells.[8] In the empirical application, we set $\beta = 1$. This means that every additional period of deprivation in a particular dimension increases each associated period of deprivation by the equivalent of $1/T$ additional dimensions of deprivation. For example, consider an individual's deprivation profile for $K = 1$ and $T = 4$; $\boldsymbol{D_i}$=(1,1,0,0). Using equation (4) and $s = \left(c_{ijt} / T \right)$,

[7]Equation (4) moves beyond a simple counting approach since it uses information on permutations of deprivation across the time dimension, and not simply combinations.

[8] The three parameters used in this study, $\alpha, \beta,$ and γ, correspond to the same parameters in Gradin et al's (2010) unidimensional model, except α only applies to deprivation across time in their specification, but α applies to both time and dimensions here.

$\mu_i = \left(\frac{1*2/4+1*2/4+0*2/4+0*2/4}{4}\right)^{\alpha}$, where deprivation in $t = (1, 2)$ is each multiplied by $2/4$ to indicate that they belong to a spell of 2 out of a maximum of 4 periods. For robustness we also consider results from $\beta = 3$ in the empirical application.

2.5: Identifying Dimensions

The generalisation found in equation (4) also yields a useful option for policy purposes. Though it may be useful, policy-wise, to identify which subgroups of the population are the most deprived, it is also useful to identify the dimensions in which individuals tend to be deprived for the longest periods of time and for the longest spells. A measure using the full form of equation (4) will be unable to do this since it simply takes the sum of deprivations and does not discriminate between the different kinds of dimensions. Consider however a specific form of equation (4) where $K = 1$.

$$\mathrm{P\Omega}_{\alpha}|_{\mathrm{j}} = \frac{\sum_{\mathrm{i=1}}^{\mathrm{N}} \left(\frac{\sum_t^T \left[d_{ijt}^0 * \left(\frac{c_{ijt}}{T} \right)^{\beta} \right]}{T} \right)^{\alpha}}{\mathrm{N}} \qquad (5)$$

Depending on the choice of α, $\mathrm{P\Omega}_{\alpha}|_{\mathrm{j}}$ potentially satisfies **TT**, **TM** and **TPM** but loses **KT** and **KM** since each dimension is considered separately; that is, it produces one $\mathrm{P\Omega}_{\alpha}|_{\mathrm{j}}$ for each of the dimensions of interest.

When $\alpha = 0$ in equation (5), we get the headcount ratio of those with at least 1 period of deprivation in the dimension of interest. When $\alpha = 1$, the measure assigns larger weights to groups deprived for more periods and for longer spells, but the weights increase in a linear fashion. When $\alpha > 1$, we get **TT**. Since (5) satisfies the basic property of Subgroup Decomposability, we can calculate it for separate population subgroups for each deprivation dimension.

Note that both the measures proposed in equations (4) and (5) incorporate the duration and persistence of deprivation. $\mathrm{P\Omega}_{\alpha}$ is recommended when the point of the analysis is to examine overall deprivation of individuals across both the *range* of deprivation (by the number of dimensions a person is deprived in at any given time) and the *duration* and/or *persistence* of deprivation. On the other hand, $\mathrm{P\Omega}_{\alpha}|_{\mathrm{j}}$ is recommended when the point of the analysis is the identification of particular dimensions over which deprivation may be particularly recurring and/or persistent.

3. THE DATA AND CHOICE OF DIMENSIONS, WEIGHTS AND SUBGROUPS

3.1: HILDA Data set and Sampling

The Household Income and Labour Dynamics in Australia (HILDA) Survey is a nationally representative household-based panel study which began in 2001 and is conducted annually. The HILDA Survey was initiated, and is funded, by the Australian Government through Department of Families, Housing, Community Services and Indigenous Affairs (FaHCSIA). Responsibility for the design and management of the survey rests with the Melbourne Institute of Applied Economic and Social Research (University of Melbourne). The HILDA Survey is a broad social and economic longitudinal survey, with particular attention paid to family and household formation, income and work.[9] The HILDA Survey began with a large national probability sample of Australian households occupying private dwellings. The Wave 1 panel consisted of 7682 households and 19,914 individuals.

The sample that is used in this study is Release 8, which has surveys of households from 2001-2008.[10] Although new entrants were included in subsequent waves, we adopt a fully balanced panel and restrict observations to those who have completed the Person Questionnaires and Self Completion Questionnaires in every period. Since the questionnaires were administered to those of 15 years of age or above at the initial survey, the sample consists of individuals who were between 15-84 years old in 2001. More than 80% of the sample is aged between 20-60 years.

HILDA's eight period balanced panel of individual respondents consists of 8414 individuals in each wave. However, because we use crucial information from the Self Completion Questionnaire, we are only able to achieve a sample size of 4175 individuals per year. This raises the question of representativeness of the information from the subsample used in relation to the larger full respondent sample. Table 1 provides some reassurance on this account by comparing the means of several demographic variables and showing that the reduced sample used here is not considerably different from the HILDA respondent sample. The variable means of the included sample are mostly within 1-2% of the corresponding means of the parent panel. However, the reduced sample are more highly educated, more

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[9] See Watson and Wooden (2004), Scutella, Kostenko and Wilkins (2009) for fuller descriptions of the HILDA data set.

[10] The data used in this paper was extracted using the Add-On package PanelWhiz for Stata®, written by Dr. John P. Haisken-DeNew (john@PanelWhiz.eu). See Haisken-DeNew and Hahn (2006) for details. The PanelWhiz generated DO file to retrieve the data used here is available upon request.

likely to have been employed and more likely to have a larger income. The difference in the mean household incomes between the included sample and the parent sample is of the order of 4%. Hence, the estimates reported later will tend to underestimate deprivation. The lack of large differences between the means of the reduced sample and the larger HILDA sample suggests that the indices to be calculated would be more representative of the population if weights designed for the HILDA respondent sample are used. This is especially true since the weights are designed to correct for parts of the population that are under sampled or that tend to attrite from surveys; this mostly includes those who are homeless, those living in institutions, those without permanent dwellings and those living in unregistered and isolated dwellings. Therefore the results presented in the next section are weighted according to the respondent sample weights provided by HILDA. These weights sum to the population level and are then rescaled to sum to the sample size.[11] If some individuals are more likely to be sampled, they receive a lower weight and therefore their characteristics have a smaller influence on the calculated averages. As with most poverty or deprivation studies, such weights will tend to reduce but not completely remove the downward bias of the estimates.

3.2: Dimensions

Eight dimensions of deprivation are considered in this study. The choice of these deprivation dimensions is consistent with, but not identical to, the Eurostat (2000) definition of social exclusion adopted in both Chakravarty and D'Ambrosio (2006) and Bossert et al (2007). A prime consideration in the choice of dimensions was their availability for each of the eight years considered in this study. Unfortunately the HILDA data was unable to provide consistent and objective information on the domains of housing conditions such as the number of rooms in the house and access to utilities such as telephones and the internet. Like most current multidimensional studies, the data limitation means the results will have to be interpreted in light of the available variables, and not as a comprehensive measure of deprivation. However, in contrast to the European Community Household Panel data, HILDA was able to provide more data on the domain of health, notably through the use of the 36 question SF-36 survey (Ware et al 2000) which aggregates responses on the survey to construct subscale indices in areas such as physical functioning and mental health.

[11]The weight attached to each observation is effectively equal to the inverse of the probability of an individual being sampled from the population. Thus, in a population (N) of 100, an equal-likelihood sample (n) of 10 individuals would each receive a weight of 10 (N/n), with each having an equal 10% chance of being sampled.

The dimensions used for this study are as follows:[12]

Dimension/Name	*Description*
i) Utilities	Inability to pay utilities bill on time in the last year.
ii) Rent	Inability to pay mortgage/rent on time in the last year
iii) Raise 2k	Inability to raise $2000 in an emergency.
iv) Heating	Unable to afford heating in the last year.
v) Meals	Unable to afford meals in the last year.
vi) Gen Health	On a general health scale of 0-100, failure to cross 20.
vii) Phy Health	On a physical health scale of 0-100, failure to cross 20.
viii) Unem	Unemployed based on the ABS (2001) definition: the individual has not worked in the last week, has looked for work within the last four weeks, and was available to start work in the last week.[13]

These eight dimensions can be grouped into three broad categories: 'material resources' (dimensions i-v); 'health' (dimensions vi & vii); and 'employment' (dimension viii). While health and material resources have often been considered in multidimensional approaches (for example, the HDI and HPI) employment captures a dimension that may be more relevant to the 'social exclusion' framework in developed countries, since it captures one's right to "participate in the basic economic ... activities of the society in which he lives" (Eurostat 2000). Unemployment is also similarly adopted in Scutella et al (2009), Atkinson, Cantillon, Marlier and Nolan (2002), and measured from an 'illfare' perspective by Paul (1992) who notes that aside from reducing income, unemployment "deteriorates human skills and leads to mental illness".

One would expect many of the dimensions to be empirically correlated, especially within each broad category, and even (to a lesser extent) across categories (for example, material wellbeing and unemployment). We should note, however, that correlated dimensions do not necessarily render one another redundant in their role as deprivation indicators. The multidimensional "functionings" approach to deprivation assumes that each dimension

[12] Appendix A details the exact questions used in the questionnaire, as well as offers more description on what defines an individual to be deprived in the respective dimension.

[13] This means the variable used to measure the unemployment dimension is unable to discriminate between short and long-term unemployment.

represents a unique area that is essential to the wellbeing of the individual. For example, more food cannot make up for a lack of access to accommodation. While it is likely that those with low incomes tend to be unable to afford both, it is also possible that there are non-income factors that affect access to accommodation, but not access to food. Atkinson (2003) gives the example, "if ... a family is prevented by discrimination from living in a better housing, then the housing (variable) acquires an independent significance" since income alone cannot entirely explain the lack of access to the good.

As a referee points out, the assignment of equal weights to each of the first five dimensions may lead to 'double counting' in the sense that each of these five dimensions is potentially capturing the same thing: the financial resources of the individual. If so, this is equivalent to allotting a weight of 5/8 to the financial resources of the individual, while only allotting a total of 3/8 to the other dimensions. To test the robustness of our results to the potential bias caused by the lack of difference between the first five dimensions, we repeat our calculations by aggregating our basic eight dimensions into the earlier discussed three broad categories of 'material resources' (dimensions i-v); 'health' (dimensions vi & vii); and 'employment' (dimension viii). These three broader categories were then equally weighted at 1/3 each, so that 'material resources' as a whole would not have more influence than either of the other two broad categories. The results were found to be almost identical to the original calculations where each of the eight dimensions was weighted equally. More generally, the principal results were found to be insensitive to the precise aggregation of dimensions (presented in Appendix C).

Note that even if one can safely assume that each dimension is unique and uncorrelated with other dimensions, the issue of the exact weight to assign to each dimension in still pertinent. The literature does not give us precise advice on this issue. The weight to attach to each dimension is largely dependent on the variables available, and the population of interest. Where data is available, a useful approach to weights is found in Bossert et al (2009) where dimensions are weighted based on the views of society regarding the importance of those dimensions ("consensus weighting"). Given the lack of such data in our Australian application, we consider the simpler approach suggested in Atkinson (2003) where all dimensions are initially weighted equally. When the eight dimensions are weighted equally, the broad category of material resources receives the largest weight of 5/8, while health receives 2/8 and unemployment 1/8. The heavier weight afforded to material resources is consistent with other multidimensional studies such as Scutella et al (2009) and Bossert et al

(2009) while unemployment is afforded the least weight since it is less relevant to some individuals who are out of the labour force. As previously stated, we also use a system of equal weights to the three broad categories, and another one where the 'material resources' category is given the least weight, and 'health' is given the most. This method of adopting a "nested constellation of weights" associated with larger groupings of dimensions is also used in Foster (2007b). The results and the corresponding specification of the weights are found in Appendix C. As confirmed by the table in this appendix, the results are insensitive to the weights attached to the dimensions.

3.3: Subgroups

The panel nature of the HILDA data has proved very convenient for the incorporation of both duration and persistence into multidimensional measures. As Scutella et al (2009) note, "no one data source is able to comprehensively measure social exclusion in Australia across the range of dimensions proposed. The closest to doing so is the HILDA survey". This study also exploits the subgroup decomposability property of the multidimensional measures in proposing measures of relative deprivation between subgroups. The three such comparisons are between: (a) residents of urban, regional and remote areas,[14] (b) non-indigenous and indigenous persons, and (c) homeowners and non-homeowners.[15] Each of these comparisons has taken on significance in the context of recent political and economic developments in Australia. For example, the outcome of the 2010 elections in Australia has, via the role of the independents in a 'hung parliament', drawn attention to the plight of the individuals living in regional and remote areas in relation to those in the major metropolitan centres. This classification is of special interest in the Australian context since there is a much greater concentration of people living in the big cities and in the urban areas in Australia than in most other developed countries. While the residents of regional and remote Australia are disadvantaged due to the tyranny of distance from modern facilities, the huge pressure on infrastructure, accommodation, transport, etc, in the cities tends to have an adverse effect of the welfare of the residents living in the metropolitan centres. It is not clear, a priori, which group is more deprived and the results presented later are both surprising and informative.

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[14] This classification is constructed according to ABS classifications adopted in the HILDA, where the 'urban' category consists of all individuals living in 'major cities', the 'regional' category being all those living in 'inner regional Australia' and the 'remote' category consist of all individuals living in regions that are classified as 'outer regional Australia' or further.

[15] Individuals are classified based on the question "Do you (or any other members of this household) own this home, rent it, or do you live here rent free?".

The distinction between homeowners and non-homeowners is of interest for several reasons. The sharp rise in house prices in recent years suggests that house ownership is imposing increasing financial constraints on households, in which case non-ownership may become a more attractive lifestyle choice. Homeowners have a higher percentage of people who are old-aged and pensioners living on fixed incomes. In contrast, non homeowners are a much more heterogenous group of individuals. Additionally, as the literature on labour mobility suggests[16], homeowners may be more likely to be unemployed due to their lower labour mobility. On the other hand, the results in Nicholas, Ray and Valenzuela (2010), showed that during a period proximate to that considered here "the regressive nature of relative price changes affected the renters much more than non-renters", suggesting that costs of living increased for non-homeowners faster than that for homeowners. Due to these diverse factors, it is not clear whether homeowners or non-homeowners are more deprived, thereby making their deprivation comparison of policy interest.

4. RESULTS

4.1 Correlation between Duration of Deprivation across Dimensions and Income

Table 2 reports the pairwise correlation magnitudes (along with the p-values) of the average duration of deprivation in the eight dimensions with one another and with the per-capita adjusted household income,[17] averaged over the period, 2001-2008. By using each individual's average (whether duration, or income) over the eight time periods, we avoid the issue of simply correlating dummy variables and also deal with individual fixed effects (which may overstate correlations).

The correlation magnitudes are all highly significant, though in absolute terms none of them seem particularly high. In general, a longer spell of deprivation in one dimension is positively correlated with a longer spell in another. There are some exceptions. For example, a longer duration of unemployment does not have any effect on the duration of deprivation in either general health or in physical health. The highest correlation at 0.685 is between the inability to pay for utilities and the inability to pay for a mortgage or rent. An increase in average income does lead to a reduction in the duration of deprivation in all dimensions, though much more for some (e.g. inability to raise $2000 in an emergency) than for others.

[16] See, for example, Munch, Rosholm and Svarer (2006).

[17]This variable is constructed for each individual using the individual's household 'financial year disposable household income' in the HILDA survey which was then adjusted with the OECD equivalence scale of $\sqrt{n}$ where n is the number of members in the household to which that individual belongs.

Notwithstanding their statistical significances, the evidence of weak correlation between average income and the average duration of deprivation suggests that large income changes will be required to bring about significant decrease in deprivation across all the dimensions.

This Australian evidence of weak correlation between the income and the non-income deprivation measures is consistent with the South African evidence of Klasen (2000) and the Spanish evidence of Ayala, Jurado and Perez-Mayo (2011). The varying magnitudes of the correlation coefficients across the dimensions suggest that exclusive reliance on income improvement may lead to varying degrees of success in reducing deprivation across the different dimensions and that policy interventions directed at particular aspect of deprivation may be more effective.

4.2: Deprivation Aggregated across Dimensions and over Time

The headcount ratios of deprivation, reported by dimensions in each year, are presented in Table 3. These deprivation rates are for the common group of 4175 individuals that constitute the panel over this period, 2001-2008. There has been a decline in deprivation in most dimensions during this period, notably in the ability to raise $2000 in an emergency and the ability to pay rent and utilities on time. Note that these are dimensions that exhibit the highest deprivation rates and that are closely linked to income. This is not surprising since for the average individual in the sample, nominal income has increased by over 50% over the eight years. On the other hand, deprivation in the health dimensions has not changed much over the years. To confirm if overall deprivation has been falling over time, we use the aggregation adopted in JS where one Ω_α is calculated for each time period; this was referred to in Section 2 as $\Omega_\alpha|_\mathrm{t}$, which is a special case of equation (3) when $T = 1$. Table 4 presents the results and confirms that there has been a decline in deprivation over time consistent with the headcount ratios reported in Table 3.

To properly compare subgroups over this period, the multidimensional deprivation index needs to be aggregated over both time and dimensions. Table 5 presents the deprivation scores calculated from this overall aggregation based on equation (3). The scores are calculated for each of the alternative subgroups mentioned previously, where N is imputed according to each subgroup's size. The corresponding ratios of the deprivation scores of the comparison subgroups are presented in Table 6. These show the relative distance (in terms of deprivation) in the bilateral comparisons between subgroups. These calculations are reported at 3 values of $\alpha = (0, 1, 3)$ of which, as explained in Section 2, the first gives us the headcount ratio of those with at least one period of deprivation in one dimension, the second gives a weighted average of the headcount ratios, with linearly increasing weights given to those who are more deprived, and the third gives exponentially increasing weights to those who are more deprived, therefore satisfying the four properties of **KT**, **TT,** Dimensional Transfer Sensitivity and Durational Transfer Sensitivity (as defined in Appendix B).

In terms of subgroups, those residing in the urban areas, the indigenous individuals and the non-homeowners are at relative disadvantage with respect to the rest of the population. Though the higher urban deprivation scores are somewhat surprising, the difference of the urban scores with the scores from regional and remote areas is marginal. In contrast, the indigenous and the non-homeowners suffer much higher deprivation than their comparison subgroups. As α increases, the ratio of the indices of the non-indigenous/indigenous and the homeowner/non-homeowner subgroups declines quite sharply. This suggests that the relative deprivation between these subgroups increases as more weight is given to individuals who are deprived. This means that not only do the average indigenous and non-homeowner (typically renters) suffer more counts of deprivation than the rest of the population, those who are deprived are more likely to be deprived in multiple dimensions and over a longer period of time. Between these two alternative groupings, the deprivation divide between homeowners and non-homeowners is larger than that between the indigenous and the non-indigenous individuals.

Note that the higher level of urban deprivation in relation to that in regional and remote areas may simply be a data artefact rather than indicative of a genuinely serious urban/non-urban divide in favour of the latter. The chosen dimensions, necessitated by the availability of information in the HILDA data set, do not include ones such as access to high speed internet, telecommunications, and access to medical and education facilities where those living in regional and remote areas are likely to be much more deprived than their urban counterparts. For example, in a recent piece in The Weekend Australian of May 14-15, 2011, entitled "The price of our great digital divide", Stuart Cunningham and Jason Potts have worked out the great divide between the 'city' and 'bush' residents in favour of the former in case of costs of entertainment. The absence of similar evidence in the present study points to a limitation of the HILDA data set, namely, that the questions are mostly around items that are of importance for the urban residents. The results should therefore only be interpreted conditional on our choice of dimensions; a wider choice of dimensions is likely to reverse the difference in overall deprivation between the urban and non-urban population that is recorded in Tables 5 and 6. We pursue this discussion further in the concluding section.

4.3: Persistence-Augmented Deprivation Measures and Dominance Criteria

Table 7 presents the persistence-augmented counterparts to the estimates reported in Table 5 using the measure given by equation (4). Table 8 presents the subgroup ratios when $\beta = (1, 3)$, where β is the sensitivity of the index with regards to persistence. That is, a higher value of β implies greater weight to deprivations associated with longer spells. A comparison of Tables 6 and 8 shows that the incorporation of persistence does not change the results significantly. However, as we increase β from 1 to 3, marginally increasing gaps between all three subgroup comparisons suggest that those who suffer more counts of deprivation (whether across time or dimensions), also tend to suffer them persistently (i.e. for consecutive periods).

The other advantage of using the persistence-augmented index according to equation (4) is the ability to establish a dominance relation between two population subgroups without the need to assume a particular form of numerical values for the individual scores. Let there be two subgroups, a and b with population deprivation profiles $\boldsymbol{\rho_a}$and $\boldsymbol{\rho_b}$ respectively. Let the individual scores μ_i in the population deprivation profiles be arranged in a non-decreasing order. Then, given the three axioms of Subgroup Decomposability, Monotonicity and Normalisation, we can unambiguously say that $\boldsymbol{\rho_a} \succ \boldsymbol{\rho_b}$, i.e. group a is more deprived than group b when:

$$\sum_{c=1}^{Z} h_c^{\alpha} < \sum_{c=1}^{Z} h_c^{b} \qquad \forall\, Z \in \{1, 2, \dots, C\} \tag{6}$$

where C is the number of possible categories or scores each individual can be assigned, and h_c^x is the deprivation headcount ratios of those belonging to subgroup x and score category $c \in \{1, 2, \dots, C\}$. I.e., $\boldsymbol{\rho_a} \succ \boldsymbol{\rho_b}$ requires that the cumulative headcount ratio of the first Z categories of deprivation in group a be less than that in group b, for all Z.

Notice that this holds for any monotonic transformation of the category scores μ_c; therefore the dominance relation is a more powerful tool (since it imposes less structure and is harder to satisfy) in terms of ranking subgroups. This relation is established in CD and also applied in JS; however, neither of those studies takes full advantage of the dynamic information available in the panel. Following equation (4), we define $C = (T * T * K)$ and present the dominance relation graphically in Figures 1-3. These curves, (called 'D-curves' in JS) show on the y axis the proportion of population that have a category deprivation score equal to or less than the score on the x axis. The intercept on the y axis shows the proportion of population that is not deprived in any dimension at any time. A shift of the D-curve towards the upper left corner suggests lower deprivation, while a shift towards the lower right corner suggests higher deprivation. The dominance relation is satisfied when the D curve of one group (e.g. b) lies entirely above the D curve of another group (e.g. a), in which case we can say that $\boldsymbol{\rho_a} \succ \boldsymbol{\rho_b}$.

Figure 1 depicts the D-curves for the 'urban' and 'remote' subgroups (the 'regional' group was removed as it closely follows that of the 'remote' area). Notice that the curves for the two subgroups intersect at some point, indicating that the dominance criteria alone is unable to allow us to conclude if one group is more deprived than the other. Figure 2 also displays a similar intersection of the two curves, though at a higher score level, suggesting that while the indigenous are more deprived than the non-indigenous for the most part, a concentration of highly deprived individuals in the non-indigenous subgroup make it impossible to satisfy the dominance criteria. In contrast, Figure 3 confirms that, even according to the stricter dominance relation, the non-homeowners are more deprived than the homeowners. Consistent with the earlier numerical results, the divide between the homeowners and non-homeowners seems larger than the divide between the indigenous and non-indigenous individuals.

4.4: Comparison with Unidimensional Income Measure

For a simple comparison with a more traditional measure, equation (3) is estimated using a single dimension ($K = 1$) – income[18] – where an individual is considered deprived in the dimension if she/he belongs to the lowest income decile at time t.[19] These results on income deprivation are presented in Table 9, with the subgroup ratios presented in Table 10.

The following significant features emerge from these tables. On purely income terms, the urban residents are the least deprived in comparison with the residents in regional and remote areas. That this result can be misleading is evident from the fact that it is inconsistent with the

[18]See footnote (17) for the meaning of this variable. Note that the results are also robust to an alternate equivalence scale specification where additional adults are given a weight of 0.5 and individual less than 15 years old are given 0.3 (the OECD 'modified' scale).

[19] When $\alpha = 0$ the deprivation ratio can be interpreted as the fraction of the population that belong to the lowest income decile for at least one out of the eight periods.

multidimensional deprivation scores presented in Tables 5 and 6. While urban residents are more affluent, income-wise, than their non-urban counterparts, urban residents turn out to be more deprived if one considers a wider range of welfare indicators. This is probably due to the heavy demand on social infrastructure and increased costs of living in urban areas. Additionally, while increasing α worsens the gap between the indigenous and non-indigenous in the multidimensional case, increasing α in the unidimensional income setting actually lowers the gap, suggesting that the non-indigenous have higher income inequality, but not necessarily higher deprivation inequality.

On the other hand, the result on the higher deprivation of the non-homeowners versus homeowners is robust between the multidimensional estimates of Tables 5 and 6 and their unidimensional income counterparts in Tables 9 and 10. Overall, a comparison of the estimates of Tables 6 and 10 suggests that the income measure understates the extent of the deprivation divide between groups, especially at higher values of α.

4.5: Analysis by Dimension

While we have so far focussed on multidimensional deprivation at the individual level, it is of policy interest to identify the specific dimensions in which individuals tend to be deprived for longer periods. This is especially true after identifying subgroups of the population who should be targeted. As is evident from Table 2 and Tables 9 & 10, income is not strongly correlated with the various deprivation indicators, in which case policies targeted at specific dimensions are warranted. Dimension-specific deprivation rates incorporating the duration and persistence of deprivation are calculated using equation (5) where one $P\Omega_{\alpha}|_{\mathrm{j}}$ is estimated for each dimension. The results for the three subgroups that have been identified as the more deprived ones are presented in Table 11. An inability to pay for utilities, rent and to raise $2000 in an emergency consistently records the highest persistence in deprivation. Additionally, while the average individual is equally likely to be deprived in physical health or general health, deprivation in the latter tends to recur and last longer.

Let us recall that that the urban population is marginally more deprived than the non-urban population: this is especially true when persistence is taken into account. Table 12 depicts the deprivation score ratios for the various subgroups from equation (5). This table shows that the urban subgroup's deprivation relative to the others is primarily driven by persistence in inability to pay mortgages and rent and, to a lesser extent, by unemployment. On the other hand, the differences between the deprivation levels of the indigenous and non-indigenous, as well as that between homeowners and non-homeowners, is primarily driven by unemployment persistence though, in case of the latter, financial factors such as the inability to raise $2000 in an emergency and to afford heating are important as well.

The fact that the indigenous, though overall more deprived than the non-indigenous, are far less likely to be physically deprived or unable to afford meals again highlights the heterogeneity in the incidence of deprivation across dimensions. This evidence points to the usefulness of the multidimensional approach that gives a more complete picture of living standards and identifies the dimensions that are the prime source of deprivation and require targeted intervention.

5. CONCLUDING REMARKS

The multidimensional deprivation measures that have been proposed and used in recent empirical applications have been static ones that do not incorporate the duration of deprivation in a particular dimension. While recent attempts have been made at introducing dynamic considerations in the context of unidimensional poverty measurement, this is the first such attempt in the context of multidimensional deprivation. This paper distinguishes between persistence and duration of deprivation, and combines the two in proposing a comprehensive multidimensional measure of deprivation. The proposed measure nests the static multidimensional measures and the dynamic unidimensional measures as special cases.

This study illustrates the use of the proposed dynamic multidimensional deprivation measure by applying it to Australian data for the period 2001-2008. The Australian application is of empirical interest because of the use of the panel information from the HILDA data set. This study exploits the property of subgroup decomposability of the multidimensional deprivation measures to compare the deprivation between alternative socio-economic groups, namely between (a) residents of the major cities and those in remote/regional areas, (b) the indigenous and non-indigenous, and (c) homeowners and non-homeowners.

While there is little difference between those living in the regional versus remote areas, the largest disparity in deprivation is found between homeowners and non-homeowners. There is close agreement between the unidimensional and multidimensional measures on the large deprivation divide between the two, in favour of the homeowners. This suggests that for the majority of the population, non-homeownership is not so much a lifestyle choice based on preferences for mobility, but rather a result of financial constraints. Homeowners are also more likely to be employed, suggesting that their lower labour mobility is more than offset by other factors.

By examining the persistence of deprivation in each of the various dimensions, the methodology proposed here identifies differences in the ability to raise money in emergencies, as well as the financial inability (or unwillingness) to pay for rent/mortgages and utilities, as key contributors to overall deprivation in Australia. While one may argue that these dimensions are clearly income related, the fungible nature of income is such that individuals may prioritise certain dimensions over others, especially when default in mortgage payments or the inability to save have no immediate consequences. This in turn suggests that there may be no improvements in certain dimensions even for a significant increase in income. The weak (though statistically significant) correlation between average income and the duration of deprivation in the various dimensions, as well as the inability of income to capture geographical differences in the cost of living, suggests that income increases are only part of the solution to improvements in individual welfare.

The multidimensional deprivation approach is favoured over the traditional unidimensional approach of money metric measurement because of its ability to take into account a wider set of deprivation indicators that provide a more complete and direct picture of individual welfare. The Australian evidence on the HILDA panel data shows that the unidimensional measure can paint a misleading picture. For example, the urban residents are marginally more deprived multidimensionally than the non-urban residents but the reverse is true in the unidimensional income context. Income deprivation understates the deprivation experienced by the urban residents. For example, the huge pressure on rental accommodation in the major metropolitan centres may cancel the income differentials that the urban residents enjoy over those living in the regional and remote areas. Coupled with the physical and psychological pressures of living in major cities and commuting large distances that lead health deprivation, this implies that the unidimensional income measure will understate the true deprivation faced by the urban residents, as our results confirm.

The policy inference from this is that the source of the difference between the urban and the non-urban residents only becomes evident when both unidimensional and multidimensional measures are compared. While the two approaches serve different purposes they jointly provide the information for effective and targeted policy interventions. Note, however, that the choice of dimensions, necessitated by the available information in the HILDA data set, especially the restriction of information largely to items that are more pressing in urban areas, may explain the magnitude and nature of divergence between deprivation in urban areas and that in regional/remote areas. A wider choice of dimensions is likely to reverse the result, suggesting that one lesson from this study is the need to collect information on a wider set of dimensions, especially ones that are of importance for the residents living in remote/regional areas. Additionally, the availability of subjective information on the importance attached to the various dimensions by the respondent, bringing HILDA in line with European panel data sets, will help in providing guidance on what weights to use in the multidimensional measures. A larger response rate to the Self Completion Questionnaires in every period would also improve the national representativeness of a multidimensional approach.

The ability of the proposed dynamic multidimensional deprivation approach to identify subgroups that are more deprived than others and to point to dimensions where deprivation is persistent makes it a powerful tool in future applications. For example, the release of HILDA 2010 ("release 10") would allow the study of the full impact of the recent global financial crisis on deprivation, especially on the differential nature of its impact between diverse socio-economic groups. In terms of methodological extensions, while the current approach allows for an analysis disaggregated by dimensions, such an approach is still limited in that it is unable to satisfy transfer and sensitivity axioms relating to the distribution of deprivation dimensions across individuals.

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Table 1: Summary Statistics for HILDA Respondent Sample and this Sample

	Hilda Respondent Sample	Included Sample	Excluded Sample	p-value of Difference in means
Observations	8414	4175	4239	
Dichotomous Variables				
Male	46.46%	45.56%	47.35%	0.10
Aboriginal/Torres Straits	1.51%	1.36%	1.65%	0.28
Bachelor degree or higher	19.96%	23.52%	16.44%	0.00
Year 12, VET certs, adv dip	41.86%	42.11%	41.64%	0.66
Year 11 and below	38.18%	34.37%	41.92%	0.00
Employed	63.61%	67.95%	59.33%	0.00
Unemployed	3.72%	2.90%	4.53%	0.00
Out of Labour Force	32.67%	29.15%	36.14%	0.00
Major City	61.49%	61.39%	61.59%	0.85
Regional	24.51%	24.29%	24.72%	0.64
Remote	14%	14.32%	13.68%	0.40
House Owner	85.10%	87.35%	82.87%	0.00
NSW	30.35%	28.67%	32.01%	0.00
VIC	24.58%	24.62%	24.53%	0.92
QLD	20.24%	20.62%	19.86%	0.39
SA	9.66%	9.82%	9.51%	0.63
WA	9.88%	10.32%	9.44%	0.17
TAS	3.05%	3.28%	2.83%	0.23
NT	0.59%	0.65%	0.54%	0.53
ACT	1.64%	2.01%	1.27%	0.01
Continuous Variables*				
Age	44.27	43.59	44.93253	0.00
	(16.32)	(14.83)	(17.65)	
Household Income	50770.72	52910.66	48663.1	0.00
	(33195.72)	(31666.23)	(34510.42)	
Number of Children	0.70	0.68	0.73	0.06
	(1.11)	(1.11)	(1.09)	
Number of Adults	2.22	2.22	2.22	0.97
	(0.90)	(0.94)	(0.86)	

*: standard deviations presented in parentheses
^: proportions test for dichotomous variables and t-test for continuous variables

Table 2: Pairwise Correlation, p-values in parentheses

	heating	meals	raise2k	rent	utilities	genhealth	phyhealth	unem
heating	1							
meals	0.5065	1						
	(0.00)							
raise2k	0.3733	0.3806	1					
	(0.00)	(0.00)						
rent	0.2593	0.4099	0.339	1				

	(0.00)	(0.00)	(0.00)					
utilities	0.3551	0.4623	0.4498	0.685	1			
	(0.00)	(0.00)	(0.00)	(0.00)				
genhealth	0.164	0.1558	0.2048	0.0505	0.0994	1		
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)			
phyhealth	0.0971	0.1093	0.1321	0.0388	0.0641	0.4344	1	
	(0.00)	(0.00)	(0.00)	(0.01)	(0.00)	(0.00)		
unem	0.1762	0.1842	0.2828	0.1849	0.2239	-0.0058	-0.0207	1
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.71)	(0.18)	
aveinc	-0.1383	-0.1371	-0.2467	-0.1444	-0.2066	-0.1063	-0.1053	-0.12
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)

Table 3: Headcount Ratios of Deprivation at Time *t* in Dimension *j*

	heating	**meals**	**raise2k**	**rent**	**utilities**	**genhealth**	**phyhealth**	**unem**
2001	0.02	0.03	0.11	0.06	0.15	0.03	0.02	0.03
2002	0.02	0.03	0.09	0.06	0.14	0.02	0.02	0.03
2003	0.02	0.03	0.09	0.06	0.12	0.03	0.02	0.02
2004	0.02	0.02	0.08	0.05	0.11	0.03	0.02	0.02
2005	0.01	0.02	0.07	0.05	0.10	0.03	0.02	0.02
2006	0.01	0.02	0.06	0.04	0.09	0.03	0.02	0.02
2007	0.01	0.02	0.06	0.04	0.09	0.03	0.02	0.01
2008	0.01	0.02	0.06	0.04	0.08	0.03	0.03	0.01

Table 4: Deprivation Scores aggregated across Dimensions

	$\alpha = 0$	$\alpha = 1$	$\alpha = 3$
2001	0.263	0.055	0.006
2002	0.239	0.049	0.005
2003	0.225	0.046	0.004
2004	0.203	0.042	0.004
2005	0.187	0.038	0.004
2006	0.176	0.035	0.003
2007	0.181	0.037	0.004
2008	0.176	0.034	0.003

Table 5: Dimension and Time-Aggregated Deprivation Scores by Population Subgroups

	Urban	Regional	Remote		Non-indigenous	Indigenous		Home-owners	Non homeowners		Total
obs	2563	1014	598		4118	57		3647	528		4175
$\alpha = 0$	0.506	0.436	0.433		0.475	0.741		0.428	0.827		0.479
$\alpha = 1$	0.043	0.041	0.040		0.042	0.095		0.031	0.119		0.042
$\alpha = 3$	0.0023	0.0020	0.0020		0.0021	0.0060		0.0012	0.0088		0.0022

Table 6: Dimension and Time-Aggregated Deprivation Score Ratios between Population Subgroups

	Urban/Regional	Urban/Remote	Non- indigenous/ Indigenous	Homeowner/ Non- owner
$\alpha = 0$	1.16	1.17	0.64	0.52
$\alpha = 1$	1.04	1.07	0.44	0.26
$\alpha = 3$	1.15	1.19	0.36	0.14

Table 7: Persistence-Augmented Deprivation Scores between Population Subgroups

	Urban	Regional	Remote		Non-indigenous	Indigenous		Home-owners	Non homeowners		Total
obs	2563	1014	598		4118	57		3647	528		4175
$\alpha = 0$	0.51	0.44	0.43		0.48	0.74		0.43	0.83		0.48
$\alpha = 1$	0.03	0.03	0.03		0.03	0.06		0.02	0.08		0.03
$\alpha = 3$	0.001	0.001	0.001		0.001	0.003		0.001	0.003		0.001

Table 8: Persistence-Augmented Deprivation Score Ratios between Population Subgroups

	Urban/Regional		Urban/Remote		Non- indigenous/ Indigenous		Homeowner/ Non- owner	
	$\beta = 1$	$\beta = 3$	$\beta = 1$	$\beta = 3$	$\beta = 1$	$\beta = 3$	$\beta = 1$	$\beta = 3$
$\alpha = 0$	1.16	1.16	1.17	1.17	0.64	0.64	0.52	0.52
$\alpha = 1$	1.03	1.03	1.09	1.08	0.42	0.41	0.24	0.24
$\alpha = 3$	1.31	1.35	1.34	1.37	0.35	0.33	0.17	0.12

Table 9: Unidimensional (Income) Deprivation Scores by Population Subgroups

	Urban	Regional	Remote		Non-indigenous	Indigenous		Home-owners	Non homeowners		Total
obs	2563	1014	598		4118	57		3647	528		4175
$\alpha = 0$	0.25	0.32	0.35		0.28	0.48		0.25	0.49		0.28
$\alpha = 1$	0.08	0.11	0.11		0.09	0.15		0.08	0.20		0.09
$\alpha = 3$	0.028	0.042	0.042		0.033	0.045		0.025	0.093		0.033

Table 10: Unidimensional (Income) Deprivation Score Ratios between Population Subgroups

	Urban/Regional	Urban/Remote	Non- indigenous/ Indigenous	Homeowner/ Non- owner
$\alpha = 0$	0.77	0.71	0.57	0.51
$\alpha = 1$	0.69	0.68	0.61	0.38
$\alpha = 3$	0.65	0.65	0.73	0.26

Table 11: Persistence-Augmented Deprivation Scores disaggregated according to Dimension and Most Deprived Subgroups*

	Full Sample (4175)				Urban (2563)				Indigenous (57)				Non-homeowners (528)		
	$\alpha = 0$	$\alpha = 1$	$\alpha = 3$		$\alpha = 0$	$\alpha = 1$	$\alpha = 3$		$\alpha = 0$	$\alpha = 1$	$\alpha = 3$		$\alpha = 0$	$\alpha = 1$	$\alpha = 3$
heating	0.066	0.015	0.002		0.063	0.007	0.0006		0.144	0.023	0.0029		0.183	0.026	0.0040
meals	0.078	0.021	0.006		0.071	0.012	0.0031		0.210	0.024	0.0018		0.225	0.044	0.0130
raise2k	0.203	0.079	0.036		0.185	0.049	0.0204		0.472	0.145	0.0582		0.522	0.208	0.1151
rent	0.171	0.048	0.013		0.167	0.033	0.0086		0.226	0.031	0.0123		0.370	0.085	0.0278
utilities	0.283	0.104	0.040		0.267	0.067	0.0212		0.505	0.132	0.0589		0.569	0.170	0.0598
genhealth	0.076	0.028	0.012		0.071	0.018	0.0071		0.161	0.071	0.0382		0.140	0.039	0.0146
phyhealth	0.077	0.022	0.007		0.074	0.008	0.0003		0.098	0.008	0.0001		0.136	0.015	0.0006
unem	0.110	0.022	0.003		0.110	0.012	0.0007		0.246	0.052	0.0144		0.227	0.034	0.0038

*: figures in parentheses denote number of observations

Table 12: Persistence-Augmented Deprivation Scores Ratios disaggregated according to Dimension and Subgroups

	Urban/Regional			Urban/Remote			Non Indigenous/Indigenous			Homeowner/Non Owner		
	$\alpha = 0$	$\alpha = 1$	$\alpha = 3$	$\alpha = 0$	$\alpha = 1$	$\alpha = 3$	$\alpha = 0$	$\alpha = 1$	$\alpha = 3$	$\alpha = 0$	$\alpha = 1$	$\alpha = 3$
heating	0.918	0.735	0.736	0.829	0.618	0.318	0.450	0.350	0.286	0.262	0.221	0.095
meals	0.825	0.869	0.908	0.701	0.823	0.846	0.361	0.536	1.867	0.246	0.185	0.137
raise2k	0.786	0.766	0.715	0.783	0.700	0.665	0.422	0.372	0.394	0.295	0.153	0.082
rent	0.982	1.268	2.219	0.868	1.258	1.981	0.754	0.965	0.566	0.380	0.256	0.138
utilities	0.901	0.842	0.709	0.789	1.009	1.569	0.553	0.520	0.368	0.419	0.317	0.275
genhealth	0.800	0.786	0.870	0.917	0.748	0.700	0.463	0.262	0.189	0.473	0.417	0.453
phyhealth	0.916	0.776	0.580	0.842	0.719	0.534	0.781	1.241	5.852	0.496	0.563	0.611
unem	1.007	1.027	1.067	0.994	1.040	0.407	0.439	0.215	0.040	0.406	0.248	0.082

Figure 1: D-Curves for Urban versus Remote resident subgroups

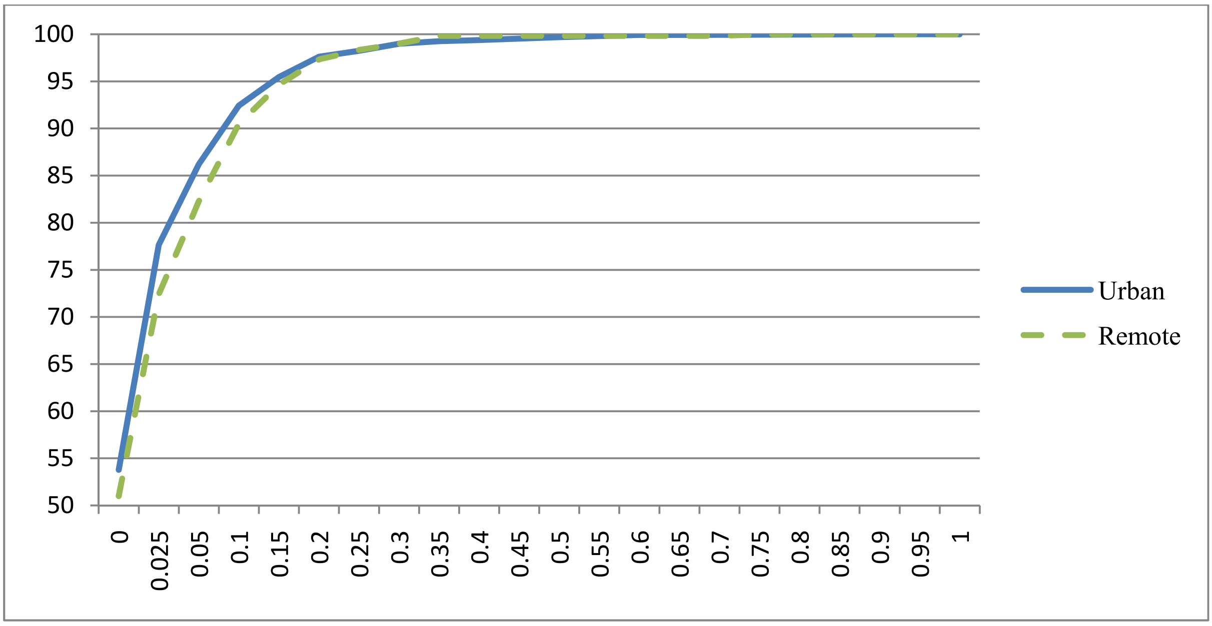


Figure 2: D-Curves for Indigenous versus Non-indigenous subgroups

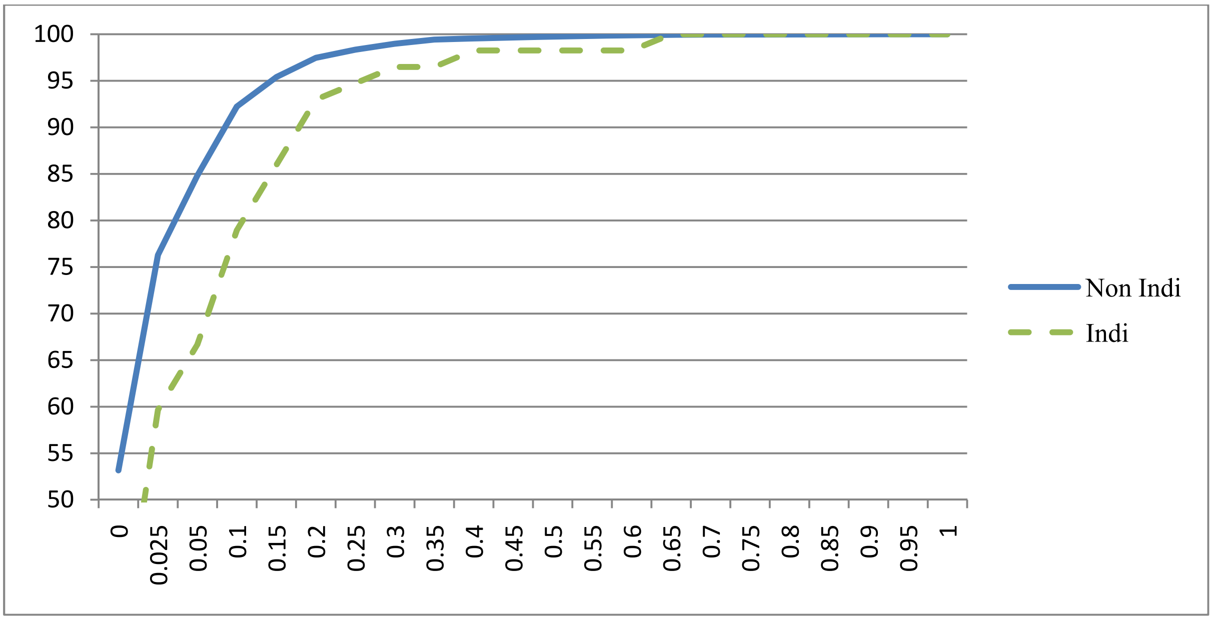
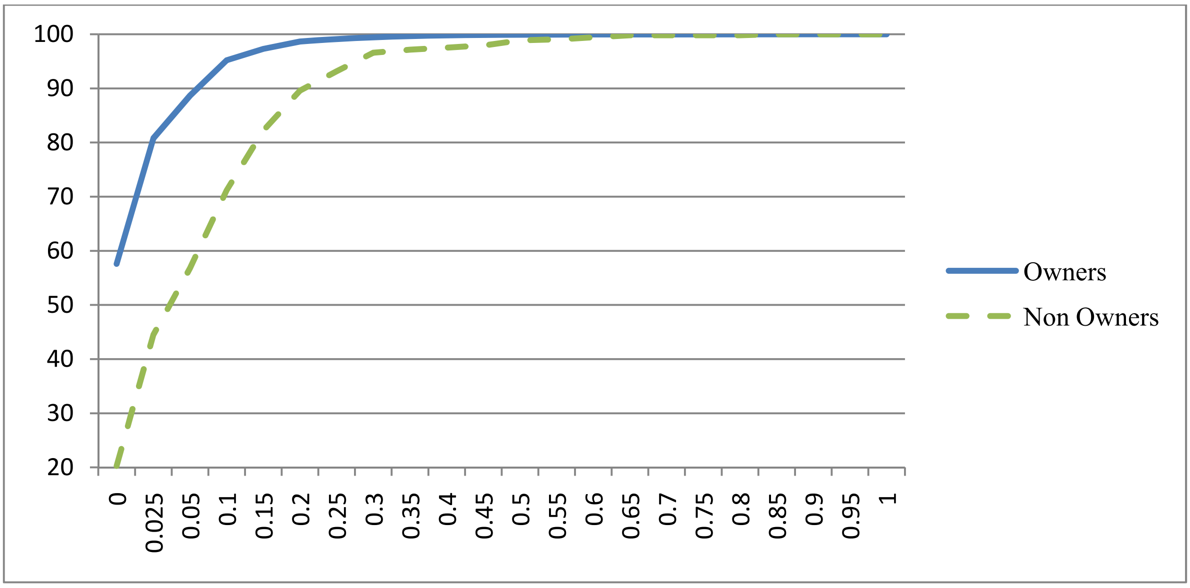


Figure 3: D-Curves for Homeowners versus Non-homeowners



Appendix A: Dimensions, Variables and Parameters with Explanations

<u>Dimensions of Deprivation</u>

1. UTILITIES	
Question	"Could not pay electricity, gas or telephone bills on time due to shortage of money in the past six months"
Description	As this is a dummy variable there is no option for determining the deprivation criteria.

2. RENT	
Question	"Could not pay the mortgage or rent on time due to shortage of money in the past six months"
Description	As this is a dummy variable there is no option for determining the deprivation criteria.

3. RAISE 2k	
Question	"Could you raise $2000 for an emergency if you only had one week?"
Description	As this is a dummy variable there is no option for determining the deprivation criteria.

4. HEATING	
Question	"Was unable to heat home due to shortage of money in the past six months"
Description	As this is a dummy variable there is no option for determining the deprivation criteria.

5. MEALS	
Question	"Went without meals due to shortage of money in the past six months"
Description	As this is a dummy variable there is no option for determining the deprivation criteria.

6. GEN HEALTH	
Question(s)	"In general, would you say your health is" "I seem to get sick a little easier than other people" "I am as healthy as anybody I know" "I expect my health to get worse" "My health is excellent"
Description	Based on the SF-36 Questionnaire (Ware et al, 2000), the five questions above, which were answered on a scale of 1-5, were used to construct the SF-36 index on General Health, which ranges from 0-100. Since 1/5 is the lowest possible, 1/5 of 100 was used as the cut-off point for determining if an individual is deprived in this dimension.

7. PHY HEALTH	
Question(s)	"Does YOUR HEALTH NOW LIMIT YOU in these activities? If so, how much?" i) VIGOROUS activities ii) MODERATE activities iii) Lifting or carrying groceries iv) Climbing SEVERAL flights of stairs v) Bending, kneeling or stooping vi) Walking MORE THAN ONE kilometre vii) Walking HALF a kilometre viii) Walking 100 metres ix) Bathing or dressing yourself
Description	Based on the SF-36 Questionnaire (REFS), the nine components above, which were answered on a scale of 1-3, were used to construct the SF-36 index on Physical Functioning, which ranges from 0-100. To be consistent with the General Health criteria, 20/100 was also used as the cut-off for deprivation in this dimension.

8. UNEM	
Question	This was constructed from several questions pertaining to employment status based on the ABS (2001) classification.
Description	**Unemployed persons** are those aged 15 years and over who satisfy all three of the following: a) The person must not be employed, i.e. they must be 'without work'. b) The person must be 'looking for work'. A person must have, at some time during the previous four weeks, undertaken specific 'active' steps to look for work, such as applied to an employer for work, answered an advertisement for a job, visited an employment agency, used a touchscreen at Centrelink offices, or contacted friends or relatives. The search may be for full-time or part-time work. In either case, however, the person must have done more than merely read job advertisements in newspapers. c) The person must be 'available to start work'. This is taken to mean that they were available to start work in the survey reference week (i.e. the week before the interview).

Unidimensional Income Measure

Construction	This was constructed using household financial year disposable income, which is the imputed income of individuals, less taxes summed to the household level. Each individual's household income is then deflated with equivalence scales to give the per-capita equivalent income associated with the individual.
Description	The equivalence scales used is the OECD 'square root' scale, which deflates household income by the square root of the number of household members. As a check for robustness, the OECD 'modified' scale is also used, which deflates household income by an additional 0.5 per additional adult from the first, and 0.3 for each child. An individual is classified as 'deprived in income' if he belongs in the last decile of the per-capita adjusted household income distribution.

Important Parameters

$\alpha \geq 0$	Increasing α increases the sensitivity of the aggregate index to the distribution of deprivations among individuals. In the application, deprivations are defined across dimensions, duration and persistence therefore α increases the weight of individuals who have a concentration of all three factors. We consider $\alpha = (1, 2,3)$ in the application.
$\beta \geq 0$	Increasing β increases the sensitivity of the index to the length of the deprivation spell associated with each count of deprivation. We consider $\beta = (1,3)$ in the application.
$\gamma \geq 0$	Increasing γ increases the sensitivity of the index to the shortfall of an individual's attribute from its defined threshold in a particular dimension. We specify $\gamma = 0$ in the application due to the use of qualitative and dichotomous variables.

Appendix B: Dimensional and Durational Transfer Principle Definitions

Let the individual deprivation profile be the matrix $\boldsymbol{D_i} = \begin{pmatrix} d_{i11}^0 & \dots & d_{i1T}^0 \\ . & \dots & . \\ d_{iK1}^0 & \dots & d_{iKT}^0 \end{pmatrix}$ where $d_{ijt} \in \{0,1\}\ \forall j \in \{1,2,\dots,K\}$, $\forall t \in \{1,2,\dots,T\}$ and $i \in \{1,2,\dots,N\}$. The individual deprivation score μ_i is some function $f\colon \boldsymbol{D_i} \to \boldsymbol{R}$ where $\boldsymbol{R}$ is the set of real numbers.

Define a *dimensional transfer* between any two individuals *a* and *b* as a reduction in the sum of elements in any one row of $\boldsymbol{D_a}$ by the amount ε, and an equivalent increase ε in the sum of elements in any one row of $\boldsymbol{D_b}$ where ε is any non-negative real number. Define in turn a *regressive dimensional transfer* as a dimensional transfer from individual *a* to *b* where for any $f(\boldsymbol{D_i})$, $\mu_a < \mu_b$ prior to the transfer.

Equivalently, define a *durational transfer* between any two individuals *a* and *b* as a reduction in the sum of any one column of $\boldsymbol{D_a}$ by the amount ε and an equivalent increase ε in the sum of any one column of $\boldsymbol{D_b}$ where ε is any non-negative real number. A *regressive durational transfer* is a durational transfer from individual *a* to *b* where for any $f(\boldsymbol{D_i})$, $\mu_a < \mu_b$ prior to the transfer.

The *population deprivation profile* is a vector $\boldsymbol{\rho} = (\mu_1, \dots, \mu_N)$ of individual scores in non-decreasing order. The *multidimensional deprivation index* Ω is then a function $g\colon \boldsymbol{\rho} \to \boldsymbol{R}$.

Definition (Dimensional Transfer Principle): If the population deprivation profile $\boldsymbol{\rho}'$ is obtained from $\boldsymbol{\rho}$ from a regressive dimensional transfer then $g(\boldsymbol{\rho}) < g(\boldsymbol{\rho}')$.

Definition (Durational Transfer Principle): If the population deprivation profile $\boldsymbol{\rho}'$ is obtained from $\boldsymbol{\rho}$ from a regressive durational transfer then $g(\boldsymbol{\rho}) < g(\boldsymbol{\rho}')$.

When the parameter $\alpha > 2$ in equations (4) and (5), two additional properties emerge:

Definition (Dimensional Transfer Sensitivity): If $\boldsymbol{\rho}'$ is derived from $\boldsymbol{\rho}$ by a regressive dimensional transfer from individual *a* to *b*, and $\boldsymbol{\rho}''$ is derived from $\boldsymbol{\rho}$ by a regressive dimensional transfer from individual *c* to *d* and additionally:

$$\mu_b - \mu_a = \mu_d - \mu_c\ ; \qquad \mu_c > \mu_a\ ; \qquad \mu_d > \mu_b$$

then $g(\boldsymbol{\rho}) < g(\boldsymbol{\rho}') < g(\boldsymbol{\rho}'')$.

Definition (Durational Transfer Sensitivity): If $\boldsymbol{\rho}'$ is derived from $\boldsymbol{\rho}$ by a regressive durational transfer from individual *a* to *b*, and $\boldsymbol{\rho}''$ is derived from $\boldsymbol{\rho}$ by a regressive durational transfer from individual *c* to *d*, and additionally:

$$\mu_b - \mu_a = \mu_d - \mu_c\ ; \qquad \mu_c > \mu_a\ ; \qquad \mu_d > \mu_b$$

then $g(\boldsymbol{\rho}) < g(\boldsymbol{\rho}') < g(\boldsymbol{\rho}'')$.

Appendix C: Robustness of Results with respect to Weighting Assumptions

Equation (5) can be further generalised to incorporate dimensional weights:

$$P\Omega^{\alpha} = \frac{\sum_{i=1}^{N} \left(\frac{\sum_{j}^{K} \left(\sum_{t}^{T} \left[d_{ijt}^{0} * s \right] w_j \right)}{T * K} \right)^{\alpha}}{N}$$

where $\sum_{j=1}^{K} w_j = 1$ and $s = \left(c_{ijt} / T \right)$

The three weighting schemes are as follows:

	1	2	3
heating	0.125	0.067	0.05
meals	0.125	0.067	0.05
raise2k	0.125	0.067	0.05
rent	0.125	0.067	0.05
utilities	0.125	0.067	0.05
genhealth	0.125	0.167	0.25
phyhealth	0.125	0.167	0.25
unem	0.125	0.333	0.25

with scheme 1 being the base-case scheme used throughout the study.

The subgroup ratios for all three schemes are as follows:

	Urban/Regional			Urban/Remote		
scheme	α =0	α =1	α =3	α =0	α =1	α =3
1	1.16	1.04	1.15	1.17	1.07	1.19
2	1.16	1.05	1.16	1.17	1.09	1.13
3	1.16	1.03	1.09	1.17	1.05	0.97
	Non Indigenous/Indigenous			Homeowner/Non Owner		
scheme	α =0	α =1	α =3	α =0	α =1	α =3
1	0.64	0.44	0.36	0.52	0.26	0.14
2	0.64	0.38	0.23	0.52	0.28	0.14
3	0.64	0.40	0.32	0.52	0.31	0.23