An investigation into the synergistic wellbeing benefits of greenspace and physical activity: Moving beyond the mean

Christopher L. Ambrey[1*]

Abstract

The purpose of this study is to move beyond a focus on mean regression estimates, to shed light on how the hypothesised synergies between greenspace and physical activity might have heterogeneous impacts across the wellbeing distribution. Using data from the Household, Income and Labour Dynamics in Australia survey and data from Geographic Information Systems, for the case of major Australian cities, this study finds some evidence that greenspace and physical activity are independently positively associated with life satisfaction, mental health and negatively associated with psychological distress. A finding which is stronger for physical activity than for greenspace. Remarkably, across measures of life satisfaction, mental health and psychological distress, the results lend support to the hypothesis that physical activity may actually be more relatively effective at mitigating the likelihood of experiencing a serious dearth of wellbeing, compared to cultivating higher levels of levels of subjectively measured wellbeing. Unexpectedly, the results do not provide support for the hypothesised synergistic wellbeing benefits of greenspace and physical activity, at conventional levels of statistical significance. A result which may attest to a more complex relationship than has tended to be hypothesised and calls for further investigation. The findings reported in this study add to the existing stock of knowledge and debate on the complex interplay between greenspace, physical activity and wellbeing from a social-ecological perspective. Further, the results presented in this study may also prove useful to policy makers wrestling with the challenges of; maintaining or improving residents' wellbeing and reducing residents' ill-being in the face of continuing population growth and declining per capita greenspace.

Keywords: Household, Income and Labour Dynamics in Australia (HILDA), Geographic Information Systems (GIS), Greenspace, Life satisfaction, Mental health, Physical activity, Psychological distress, Wellbeing

[1] Urban Research Program (URP), Gold Coast Campus, Griffith University, Queensland 4222, Australia. Email: c.ambrey@griffith.edu.au

1. Introduction

A number of studies (Bodin & Hartig, 2003; Hug et al., 2009; cf. Mitchell, 2013; Pretty et al., 2007; Thompson Coon et al., 2011) have hypothesised a synergistic link between the well-established physiological and psychological benefits of physical activity, and the restorative effects of contact with a natural environment. Despite the best efforts many earlier investigators many caveats continue to surround the triadic relationship between the greenspace, physical activity and wellbeing (Mitchell, 2013). Pinder et al. (2009, 349) paint the picture clearly when they declare that, "There is no inevitable, or straightforward, relationship between environment and health benefit. It has become impossible to consider the 'natural environment' and the human body as separate entities in any simplistic way… people-in-environments are complex systems, with multiple pathways interlinking space and health."

Distinct from this body of literature, there is evidence emerging from the empirical economic and psychological literature which suggests that positive and negative wellbeing are more than merely opposite ends of the same phenomenon (Boes & Winkelmann, 2010). In this vein, the purpose of this study, is to go beyond earlier research efforts by moving beyond a focus on the mean regression estimates to reveal how potential the synergies between greenspace and physical activity might have heterogeneous impacts on positive and negative wellbeing. In doing so, for the case of major Australian cities, this study contributes to, the stock of knowledge regarding the interplay between greenspace, physical activity and wellbeing. The findings presented may prove useful to policy makers wrestling with the challenges of; maintaining or improving residents' wellbeing and reducing residents' ill-being in the face of continuing population growth and declining per capita greenspace. In what follows, Section 2 reports the method and data employed. Section 3 provides an account of the results and Section 4 discusses the findings and concludes.

2. Method

The following microeconometric wellbeing function is modelled for each wellbeing measure, using four conditional logistic regression models, one for each quartile of the dependent variable within a seemingly unrelated regression (SUR) system.[2] The dependent variable $\mathrm{WB}_{q_{1\ldots4}\,\mathrm{r,k,t}}$ represents a resident's life satisfaction, or mental health or psychological distress each of which have been disaggregated into $q_{1\ldots4}$ quartiles as show in Equation 1.

$$\mathrm{WB}_{q_{1\ldots4}\,\mathrm{r,k,t}} = \begin{cases} 0 \; if \; WB^*_{r,k,t} \; \leq WB^* \\ 1 \; if \; WB^*_{r,k,t} \; > WB^* \end{cases} \quad \text{where } WB^* = \; Quartile_{q=1\ldots4}\left(WB^*_{r,k,t}\right) \qquad (1)$$

Equation 2 illustrates the conditional logistic regression models within the seemingly unrelated regression (SUR) system.

$$\mathrm{WB}_{q_{1\ldots4}\,\mathrm{r,k,t}} = \omega + \textstyle\sum_{\mathrm{j=1}}^{\mathrm{m}} \beta_{\mathrm{j}} \mathrm{x}_{\mathrm{r,k,t}} + \gamma \mathrm{x}_{\mathrm{r,k,t}} \mathrm{y}_{\mathrm{r,k,t}} + \kappa_{\mathrm{k}} + \varepsilon_{\mathrm{r,k,t}} \qquad (2)$$

Where, $\mathrm{x}_{\mathrm{r,k,t}}$ is a vector of socioeconomic variables such as, age, gender, ethnicity and importantly a measure of physical activity and greenspace. $\mathrm{x}_{\mathrm{r,k,t}}\mathrm{y}_{\mathrm{r,k,t}}$ represents the two-way interaction term of linear term greenspace $\times$ physical activity. κ_{k} represents the Local Government Area (LGA)-specific fixed effects. Finally, $\varepsilon_{\mathrm{r,k,t}}$ is the error term.

[2] The models estimated for each quartile are based on the same data, they are not independent from each other and hence their residuals are likely correlated. As such the regression results for the separate estimations are combined using Stata's 'suest' postestimation command.

In terms of the socioeconomic data on residents this is obtained from waves 13 (2013) of the Household, Income and Labour Dynamics in Australia (HILDA) Survey. The sampling design of the survey involves the selection of households into the sample by a multi-stage process. To begin with, a random sample of 488 Census Collection Districts (CDs) based on the 1996 census boundaries was selected from across Australia, stratified by State, and within the five largest States in terms of population, by metropolitan and non-metropolitan regions, each CD consisting of approximately 200 to 250 households. The CDs were sampled with probability proportional to their size as measured by the number of dwellings (unoccupied and occupied) recorded in the 1996 Census with some adjustments for population growth since the Census. Within each of these CDs, all dwellings were fully enumerated and a sample of 22 to 34 dwellings randomly sampled based on the expected response and occupancy rates within each area (Watson & Wooden, 2002).

These data are subset the major capital cities of Australia.[3] The life satisfaction variable is obtained from residents' responses to the question*: 'All things considered, how satisfied are you with your life?'* The life satisfaction variable is an ordinal variable, the resident choosing a number between 0 (totally dissatisfied with life) and 10 (totally satisfied with life). The mental health variable is measured by the SF-36 Health Survey (within the HILDA Survey), an internationally recognised diagnostic tool for assessing functional health status and well-being. The Mental Component Summary (MCS) (0-100) used represents the aggregation of a subset of eight scales, vitality, social functioning, role-emotional and mental health, derived from 36 items, transformed to a 0-100 index using 1995 Australian Bureau of Statistics population norms (Australian Bureau of Statistics, 1995; Ware et al., 2000). The psychological distress variable is measured by the Kessler Psychological Distress Scale (K10) also collected in the HILDA Survey. The ten questions and their selection are described at length in Kessler et al. (2002), as explained by Wooden (2009) the K10 score was derived by scoring responses on each of the items using a simple linear scale running from 5 (all of the time) to 1 (none of the time), and summing across all items. The overall score thus ranges from 10 to 50.

Apart from the different dependent variables employed, the key measure of physical activity is derived from dichotomising the total physical activity Metabolic Equivalent of Task (MET) minutes per week (International Physical Activity Questionnaire). The variable is defined as *'Exercising as recommended (MET)'* (1) or not (0), where exercising as recommended is defined as MET minutes per week greater than 840 and less than 10,000. That is, the equivalent of 30 or more min × week × 4 MET. To avoid measurement error due to over-reporting, those reporting energy expenditure of 10,000 MET (min/week) or more were excluded (Giles-Corti & Donovan, 2002). Exercising as recommended was defined as the accumulation of the equivalent of 30 min or more of moderate physical activity on most days of the week (US Department of Health, 1996).

Data from the HILDA survey are linked to Geographic Information Systems (GIS) data on greenspace through the resident's Census Collection District (CD). Using GIS CDs are overlayed with greenspace measured from PSMA Australia Limited Transport and Topography dataset. Greenspace in this instance, includes for instance, public parks, community gardens, cemeteries, sports fields, national parks and wilderness areas (cf. Bell et al., 2008). The variable is the number of hectares of greenspace per resident in the CD. A detailed description and summary statistics of the key variables are provided Table 1.

[Table 1 here]

[3] Major capital cities in Australia include: Adelaide, Brisbane, Canberra, Darwin, Melbourne, Perth and Sydney.

3. Results

The key results, for Equation 2 are reported in Tables 2, 3 and 4. With regards to the life satisfaction variable (Table 2), columns 1 to 4 suggest that, independently and distinct from any synergistic effect, both greenspace (odds of reporting a life satisfaction score in the first quartile = 0.9452, [0.9023,0.9902], *p*-value<0.05) and physical activity (odds of reporting a life satisfaction score in the first quartile = 0.8128, [0.7114,0.9288], *p*-value<0.01), reduce the likelihood of reporting a life satisfaction score in the first quartile.

While the estimates for greenspace and physical activity are stronger and more precise than the other quartiles, the results provide no evidence of the hypothesised synergistic benefits of greenspace and physical activity for wellbeing at conventional levels of statistical significance. Nevertheless, it is worth noting that in column 4 (fourth quartile) the interaction term between greenspace and physical activity (odds of reporting a life satisfaction score in the fourth quartile = 1.6605, [0.9002,3.0630], *p*-value=0.11) close to being statistically significant at the 10% level.

[Table 2 here]

In terms of the mental health variable (Table 3), columns 1 to 4 suggest that greenspace is only be statistically significant for the third quartile (odds of reporting a mental health score in the third quartile = 0.7828, [1.0213,1.1841], *p*-value<0.01), net of any synergistic effects. Further, physical activity is found to have an independently greater estimated effect on reducing the likelihood of reporting a mental health score in the first quartile (odds of reporting a mental health score in the first quartile = 0.7828, [0.6995,0.8760], *p*-value<0.01) compared to the other quartiles, distinguished from hypothesised synergistic psychological benefits. For mental health like for life satisfaction, Table 3, columns 1 to 4, yield no evidence of synergistic psychological benefits.

[Table 3 here]

For the case of psychological distress variable (Table 4), columns 1 to 4 reveal that only physical activity, net of hypothesised synergistic psychological benefits is generally associated with lower levels of psychological distress. Greenspace is not found to be statistically significantly linked to psychological distress holding constant any synergistic effect. However, physical activity (odds of reporting a psychological distress score in the first quartile = 1.3025, [1.1020,1.5396], *p*<0.01) is linked to a higher estimated likelihood of reporting lower levels of psychological distress. Corroborating this general finding, although marginally less compelling, the results for the third (odds of reporting a psychological distress score in the third quartile = 0.8515, [0.7461,0.9718], *p*<0.05) and fourth (odds of reporting a psychological distress score in the fourth quartile = 0.8622, [0.7536,0.9863], *p*<0.05) quartiles point to a lower chance of reporting higher degrees of psychological distress for those that physical activity. For psychological distress as for life satisfaction and mental health, Table 4, columns 1 to 4, also fall short of providing evidence of synergistic psychological benefits.

[Table 4 here]

4. Discussion

The results provide some evidence that greenspace and physical activity are independently positively associated with life satisfaction, mental health and negatively associated with psychological distress. A finding robust to a battery of controls and replicable using easily transferable outcome measures (Thompson Coon et al., 2011). This general finding is stronger for physical activity than for greenspace.

Beyond these general findings, the results lend support to the hypothesis that separately physical activity may actually be more relatively effective at mitigating the likelihood of experiencing a serious dearth of wellbeing, rather than cultivating higher levels of levels of subjectively measured wellbeing. A convincing finding given that estimated effects for poor wellbeing are likely to be bias downwards (cf. Mitchell, 2013, 133). This implies that physical activity may be a more effective remedy to poor wellbeing, the minimisation of which is also an idea that policy makers may be more comfortable with, rather than maximising positive wellbeing or the more nebulous concept of happiness per se (Kahneman & Krueger, 2006).

Furthermore, this study finds no evidence of the hypothesised synergistic wellbeing benefits of greenspace and physical activity. At least not at conventional levels of statistical significance. This lack of evidence however, does not constitute evidence that no such relationship exists, rather that this study has merely been unable to find such a relationship. The absence of a link between greenspace and physical activity while not commonly hypothesised is not unheard of, Hoehner et al. (2005) and Hillsdon et al. (2006) fail to find a link between greenspace and hours of recreational physical activity. Further, Mytton et al. (2012), despite finding a positive link between greenspace and physical activity also conclude that it may not necessarily be attributable to greenspace being used for physical activity in the ways we might expect, e.g. for running, cycling, walking, or football/rugby. For these reasons, the triadic relationship between greenspace, physical activity and wellbeing may in fact be more complicated than has tended to be hypothesised. For instance, the realisation of hypothesised synergistic benefits may be contingent on particular individual, social environmental and physical environmental conditions such as fear of crime in the neighbourhood (cf. Sreetheran & van den Bosch, 2014) or different dimensions of a resident's social environment (cf. McNeill et al., 2006). Further research from is needed to disentangle the complexity that surrounds the links between greenspace, physical activity and wellbeing.

In all, this study highlights differences, and at times, the lack thereof, across the wellbeing distribution, beyond the mean. In doing so, this study builds on an existing literature to make inferences about different groups across the distribution of wellbeing, giving a voice to those residents who fall further away from the mean. As a result, this study adds to the existing body of knowledge on the hypothesised synergies between the well-established physiological and psychological benefits of physical activity, and the restorative effects of contact with a natural environment. Apart from providing a distinct contribution to the literature, these finding may also prove useful to decision makers faced with the challenge of maintaining or improving the health and wellbeing of residents in the face of continued population growth in urban centres.

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References

Australian Bureau of Statistics. (1995). 4399.0 - National Health Survey: SF36 Population Norms. Canberra: Australian Bureau of Statistics.

Bell, S., Hamilton, V., Montarzino, A., Rothnie, H., Travlou, P., & Alves, S. (2008). Greenspace Scotland Research Report: Greenspace and Quality of Life: A Critical Literature Review. In G. Scotland (Ed.). Stirling.

Bodin, M., & Hartig, T. (2003). Does the outdoor environment matter for psychological restoration gained through running? *Psychology of Sport and Exercise,* 4, 141-153.

Boes, S., & Winkelmann, R. (2010). The effect of income on general life satisfaction and dissatisfaction. *Social Indicators Research,* 95, 111-128.

Giles-Corti, B., & Donovan, R. (2002). The relative influence of individual, social and physical environment determinants of physical activity. *Social Science & Medicine,* 54.

Hillsdon, M., Panter, J., Foster, C., & Jones, A. (2006). The relationship between access and quality of urban green space with population physical activity. *Public Health,* 120, 1127-1132.

Hoehner, C.M., Brennan Ramirez, L.K., Elliott, M.B., Handy, S.L., & Brownson, R.C. (2005). Perceived and objective environmental measures and physical activity among urban adults. *American Journal of Preventive Medicine*, 28, 105-116.

Hug, S.-M., Hartig, T., Hansmann, R., Seeland, K., & Hornung, R. (2009). Restorative qualities of indoor and outdoor exercise settings as predictors of exercise frequency. *Health & Place,* 15, 971-980.

Kahneman, D., & Krueger, A. (2006). Developments in the measurement of subjective well-being. *Journal of Economic Perspectives,* 20, 3-24.

Kessler, R., nbsp, C, Andrews, G., Colpe, L., nbsp, et al. (2002). Short screening scales to monitor population prevalences and trends in non-specific psychological distress. *Psychological Medicine,* 32, 959-976.

McNeill, L., Kreuter, M., & Subramanian, S. (2006). Social environment and physical activity: A review of concepts and evidence. *Social Science & Medicine,* 63, 1011-1022.

Mitchell, R. (2013). Is physical activity in natural environments better for mental health than physical activity in other environments? *Social Science & Medicine,* 91, 130-134.

Mytton, O.T., Townsend, N., Rutter, H., & Foster, C. (2012). Green space and physical activity: An observational study using Health Survey for England data. *Health & Place,* 18, 1034-1041.

Pinder, R., Kessel, A., Green, J., & Grundy, C. (2009). Exploring perceptions of health and the environment: A qualitative study of Thames Chase Community Forest. *Health & Place,* 15, 349-356.

Pretty, J., Peacock, J., Hine, R., Sellens, M., South, N., & Griffin, M. (2007). Green exercise in the UK countryside: Effects on health and psychological well-being, and implications for policy and planning. *Journal of Environmental Planning and Management,* 50, 211-231.

Sreetheran, M., & van den Bosch, C.C.K. (2014). A socio-ecological exploration of fear of crime in urban green spaces – A systematic review. *Urban Forestry & Urban Greening,* 13, 1-18.

Thompson Coon, J., Boddy, K., Stein, K., Whear, R., Barton, J., & Depledge, M.H. (2011). Does participating in physical activity in outdoor natural environments have a greater effect on physical and mental wellbeing than physical activity indoors? A systematic review. *Environmental Science & Technology,* 45, 1761-1772.

US Department of Health, H.S. (1996). Physical activity and health. A report of the Surgeon General. Atlanta, Georgia: US Department of Health and Human Services, Centres for Disease Control and Prevention, National Center for Chronic Disease Prevention and Health Promotion.

Ware, J., Snow, K., & Kosinski, M. (2000). *SF-36 Health Survey: Manual and Interpretation Guide*. Lincoln, RI: Quality Metric Incorporated.

Watson, N., & Wooden, M. (2002). The Household, Income and Labour Dynamics in Australia (HILDA) Survey: Wave 1 survey methodology. Project technical paper series no. 1/02. Melbourne: Melbourne Institute of Applied Economic and Social Research, The University of Melbourne.

Wooden, M. (2009). Use of the Kessler Psychological Distress Scale in the HILDA Survey. HILDA Project Discussion Paper Series, No. 2/09. Melbourne: Melbourne Institute.

Table 1: Key model variables

Variable name	Definition	Mean (std. dev.)	%
Dependent variables			
Life satisfaction	Resident's life satisfaction (0-10)	7.9258 (1.3664)	
Mental health	Resident's SF-36 Mental Component Summary (MCS) (0-100)	48.83 (10.30)	
Psychological distress	Resident's Kessler Psychological Distress Scale (K10) score (10-50)	15.69 (6.24)	
Independent variables			
Exercise as recommended (MET)	Resident has Metabolic Equivalent of Task (MET) minutes per week greater than 840 and less than 10,000. That is, the equivalent of 30 or more min × week × 4 MET		63.6%
Greenspace (ha) per capita	The amount of greenspace in a resident's CD per resident in the CD. Greenspace in this instance, includes for instance, public parks, community gardens, cemeteries, sports fields, national parks and wilderness areas	20.1 (27.6)	
Population density (residents per ha)	Residents in the CD per hectare	61.0 (62.9)	

Table 2: Key life satisfaction model results[4]

	(1) First quartile	(2) Second quartile	(3) Third quartile	(4) Fourth quartile
	Odds ratio (standard error) [95% CI]	Odds ratio (standard error) [95% CI]	Odds ratio (standard error) [95% CI]	Odds ratio (standard error) [95% CI]
Life satisfaction				
Greenspace (ha) per capita	0.9452**	1.2037	0.8673	0.6022
	(0.0224)	(0.2054)	(0.2378)	(0.1861)
	[0.9023,0.9902]	[0.8616,1.6816]	[0.5067,1.4845]	[0.3286,1.1035]
Exercise as recommended (MET)	0.8128***	1.0464	1.0776	1.1550
	(0.0553)	(0.0608)	(0.0803)	(0.1247)
	[0.7114,0.9288]	[0.9337,1.1726]	[0.9312,1.2471]	[0.9347,1.4271]
Greenspace (ha) per capita X Exercise as recommended (MET)	0.9908	0.7333	1.3784	1.6605
	(0.0766)	(0.1477)	(0.3850)	(0.5187)
	[0.8514,1.1530]	[0.4942,1.0882]	[0.7972,2.3831]	[0.9002,3.0630]
Summary statistics				
Observations	6082			
Groups	131			

** $p < 0.05$, *** $p < 0.01$ Standard errors in parentheses adjusted for clustering at the LGA level. Other controls included: Age, gender, ethnicity, marital status, parenting, health, educational attainment, employment status, manual work, income, social desirability bias, free time, social interaction, household members engaged in physical activity, personality traits, years at current address, years interviewed, proximity to lake, proximity to river, proximity to coastline and the SEIFA 2011 Index.

[4] Note, variance inflation factors of a base model with no interaction terms shows no sign of worrisome multicollinearity.

Table 3: Key mental health model results[5]

	(1) First quartile	(2) Second quartile	(3) Third quartile	(4) Fourth quartile
	Odds ratio (standard error) [95% CI]	Odds ratio (standard error) [95% CI]	Odds ratio (standard error) [95% CI]	Odds ratio (standard error) [95% CI]
Mental health				
Greenspace (ha) per capita	0.9735	0.8105	1.0997**	0.9526
	(0.0323)	(0.1318)	(0.0415)	(0.0396)
	[0.9122,1.0389]	[0.5892,1.1148]	[1.0213,1.1841]	[0.8781,1.0335]
Exercise as recommended (MET)	0.7828***	0.9096	1.1704**	1.1384
	(0.0449)	(0.0630)	(0.0809)	(0.0828)
	[0.6995,0.8760]	[0.7942,1.0418]	[1.0221,1.3403]	[0.9871,1.3128]
Greenspace (ha) per capita X Exercise as recommended (MET)	0.9964	1.1895	0.9933	1.0032
	(0.0823)	(0.2174)	(0.0493)	(0.0593)
	[0.8474,1.1716]	[0.8314,1.7020]	[0.9013,1.0947]	[0.8934,1.1265]
Summary statistics				
Observations	6082			
Groups	131			

** $p < 0.05$, *** $p < 0.01$ Standard errors in parentheses adjusted for clustering at the LGA level. Other controls included: Age, gender, ethnicity, marital status, parenting, health, educational attainment, employment status, manual work, income, social desirability bias, free time, social interaction, household members engaged in physical activity, personality traits, years at current address, years interviewed, proximity to lake, proximity to river, proximity to coastline and the SEIFA 2011 Index.

[5] Note, variance inflation factors of a base model with no interaction terms shows no sign of worrisome multicollinearity.

Table 4: Key psychological distress model results[6]

	(1) First quartile	(2) Second quartile	(3) Third quartile	(4) Fourth quartile
	Odds ratio (standard error)	Odds ratio (standard error)	Odds ratio (standard error)	Odds ratio (standard error)
Psychological distress				
Greenspace (ha) per capita	1.2593	0.8110	0.9566	0.9510
	(0.5505)	(0.1669)	(0.0406)	(0.0472)
	[0.5346,2.9666]	[0.5418,1.2140]	[0.8802,1.0397]	[0.8629,1.0481]
Exercise as recommended (MET)	1.3025***	1.0587	0.8515**	0.8622**
	(0.1111)	(0.0623)	(0.0574)	(0.0592)
	[1.1020,1.5396]	[0.9435,1.1880]	[0.7461,0.9718]	[0.7536,0.9863]
Greenspace (ha) per capita X Exercise as recommended (MET)	0.7885	1.3319	1.0113	0.9422
	(0.3463)	(0.2681)	(0.0621)	(0.1233)
	[0.3334,1.8650]	[0.8977,1.9761]	[0.8967,1.1405]	[0.7291,1.2176]
Summary statistics				
Observations	6076			
Groups	130			

** $p < 0.05$, *** $p < 0.01$ Standard errors in parentheses adjusted for clustering at the LGA level. Other controls included: Age, gender, ethnicity, marital status, parenting, health, educational attainment, employment status, manual work, income, social desirability bias, free time, social interaction, household members engaged in physical activity, personality traits, years at current address, years interviewed, proximity to lake, proximity to river, proximity to coastline and the SEIFA 2011 Index.

[6] Note, variance inflation factors of a base model with no interaction terms shows no sign of worrisome multicollinearity.