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3 **Demand response to improved walking infrastructure:**

4 **A study into the economics of walking and health behaviour change**

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15
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1 **Demand response to improved walking infrastructure:**

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4 **Abstract**

5 Walking is the most common form of moderate-intensity physical activity among adults, is
6 widely accessible and especially appealing to obese people. Most often policy makers are
7 interested in valuing the effect on walking of changes in some characteristics of a
8 neighbourhood, the demand response for walking, of infrastructure changes. A positive
9 demand response to improvements in the walking environment could help meet the public
10 health target of 150 minutes of at least moderate-intensity physical activity per week. We
11 model walking in an individual's local neighbourhood as a 'weak complement' to the
12 characteristics of the neighbourhood itself. Walking is affected by neighbourhood
13 characteristics, substitutes, and individual's characteristics, including their opportunity cost
14 of time. Using compensating variation, we assess the economic benefits of walking and how
15 walking behaviour is affected by improvements to the neighbourhood. Using a sample of
16 1,209 respondents surveyed over a 12 month period (Feb 2010-Jan 2011) in East Belfast,
17 United Kingdom, we find that a policy that increased walkability and people's perception of
18 access to shops and facilities would lead to an increase in walking of about 36
19 minutes/person/week, valued at £13.65/person/week. When focusing on inactive residents,
20 a policy that improved the walkability of the area would lead to guidelines for physical
21 activity being reached by only 12.8% of the population who are currently inactive.
22 Additional interventions would therefore be needed to encourage inactive residents to
23 achieve the recommended levels of physical activity, as it appears that interventions that

1 improve the walkability of an area are particularly effective in increasing walking among
2 already active citizens, and, among the inactive ones, the best response is found among
3 healthier, younger and wealthier citizens.

4 **Highlights**

- 5 • First paper to model the demand response for walking using weak complementarity
- 6 • First paper to model effects of investment in walking infrastructure on walking
7 behaviour
- 8 • Maximizing walkability increases walking on average by 36 minutes/person/week
- 9 • Urban renewal programs can be designed to improve the health of inactive residents
- 10 • Through walkability upgrades guidelines for physical activity are met by 12.8% of
11 inactive people

12

13 **Keywords:** United Kingdom, revealed preferences, demand response, walking, weak
14 complementarity; valuation

15

1 **1. Introduction**

2 An increasing proportion of the population being overweight or obese in most Western
3 societies is leading to a significant burden on society and contributing to the rise of
4 conditions such as diabetes, cardiovascular disease and cancer (James et al, 2004; WHO,
5 2011). Physical activity levels are on the decline in Northern Ireland, as in other countries,
6 including England, (Farrell et al, 2013, SportNI, 2010), with 60% of the local adult population
7 not meeting the recommended levels of activity (DHSSPS, 2011). Physical inactivity, in
8 addition to unhealthy diet, has fuelled the rising level of obesity within the population, with
9 59% of adults in Northern Ireland either overweight or obese (DHSSPS, 2011). Obesity has
10 become an economic burden as well as a major health problem (Müller-Riemenschneider et
11 al. 2007) and, as a result, governments and public health agencies are diverting considerable
12 resources to prevent obesity and promote healthy lifestyles (Fit Futures, 2006; Butland et
13 al., 2007; DHSSPS, 2010). The UK Department of Health recommends that adults should aim
14 to be physically active on a daily basis and over the period of a week should aim to achieve
15 at least 150 minutes of moderate intensity physical activity in bouts of 10 minutes or more
16 (DoH, 2011a). Significant health consequences arise from not meeting the recommended
17 levels of activity, including higher relative risk (adjusted for known confounders) of
18 coronary heart disease, type 2 diabetes, breast cancer, colon cancer and all-cause mortality
19 (Lee et al, 2012). However if the recommended guidelines for physical activity are met, then
20 the population can expect a lower average Body Mass Index (BMI), a reduced incidence of
21 lifestyle diseases related to obesity, such as type 2 diabetes mellitus and high blood
22 pressure, and lower associated healthcare costs (Frank et al, 2009, Auchincloss et al, 2009,
23 Ogilvie et al, 2007).

1 Walking is the most common form of moderate-intensity physical activity among adults
2 (Siegel et al, 1995; Eyster et al, 2003; Ogilvie et al, 2007; Sport NI, 2010), is widely accessible
3 and especially appealing to obese people, who are less likely to perform vigorous-intensity
4 physical activity (Erlichman et al, 2002). It is an aerobic exercise that confers the diverse
5 health benefits of physical activity with few adverse effects (Morris and Hardman, 1997).
6 Several studies have confirmed that walking reduces the development of cardiovascular
7 diseases (Jones and Eaton, 1994; Albright and Thompson, 2006; Boone-Heinonen et al.,
8 2010), even though the health improvements are smaller for obese people (Boone-
9 Heinonen et al., 2010).

10 Many factors influence or facilitate the choice to walk for either travel or recreational
11 purposes, including the availability of footpaths, the attractiveness of the route (e.g.
12 interesting facades, a variety of architecture, the absence of long, blank walls), route choices
13 for variety and safety, the number of destinations within a walkable distance (e.g. work
14 places or nearby shops), and the opportunity cost of walking. Walking interventions include
15 education and encouragement, as well as infrastructure investments, such as better street
16 lighting, improved footpaths, and the creation of attractive green open spaces. Behavioural
17 changes can arise from the increases in access, attractiveness, safety, comfort and security
18 that these improvements offer (Krizek et al, 2009).

19 Interventions aimed at increasing walking have been shown to be effective (Ogilvie et al,
20 2007), but policy makers making investment decisions aimed at improving the infrastructure
21 for walking may wish to consider the costs and the benefits of such interventions (Dallat et
22 al, 2014). Whilst their costs can relatively easily be quantified using market data, the
23 monetary benefits of such interventions, in terms of increased walking, are more difficult to
24 assess and estimate (Litman, 2003). One notable exception is the World Health

1 Organization's Health Economic Assessment Tool (HEAT) for estimating the monetary health
2 benefits from reduced mortality from interventions aimed at increasing walking and cycling
3 (Kahlmeier, 2010; WHO, 2014). This paper aims to quantify such benefits in monetary terms
4 and to answer the following questions. What is the monetary value and the demand for
5 walking in an individual's neighbourhood? How are these monetary benefits and demand
6 affected by the characteristics of the neighbourhood, and by its improvements? What is the
7 value of the health benefits that might accrue from the additional walking associated with
8 the demand response to neighbourhood improvements? How do these benefits vary for
9 respondents with different health levels?

10 We address these questions by proposing an economic model of walking, based on the
11 assumption that walking in a neighbourhood is affected by the characteristics of the
12 neighbourhood itself, substitutes for walking in the neighbourhood and that walking is a
13 function of the value of time.

14 In the next section, we review previous studies on the economics of walking. Section three
15 describes our economic model for walking. Section four presents the case study of walking
16 in East Belfast, Northern Ireland. The results of the econometric analysis are reported in
17 section five, with section six presenting forecasts of demand response (resulting behaviour
18 change) and welfare calculations. Section seven concludes with a discussion of the results
19 and suggestions for further research.

20

21 **2. The economics of walking**

22 Several studies have successfully modelled the economics of walking, spanning the well
23 developed disciplines of outdoor recreation (see Burt and Brewer, 1971, McConnell and
24 Strand, 1981, Herriges and Kling, 1999), active transportation (see Button, 2010), and health

1 related physical activity (Humphreys and Ruseski, 2007 and 2011). Jones and Eaton (1994),
2 investigating how walking affects the relative risk of developing coronary heart disease,
3 found that if all inactive people began walking regularly, the US would save US\$4.3bn
4 annually. Other studies have focussed on both cycling and walking. Saelensminde (2004)
5 conducted a cost–benefit analysis of walking and cycling track networks in three Norwegian
6 cities taking into account insecurity, health effects and external costs of motorized traffic.
7 The health-economic benefits from both walking and cycling varied considerably between
8 the three cities and ranged between US\$16million and US\$258million. Wang et al (2005)
9 compared direct medical costs between active and inactive people to assess costs and
10 benefits of building and maintaining new bike/pedestrian trails, finding a benefit cost ratio
11 of 2.94. Sustrans (2006), in a cost-benefit analysis of three walking and cycling routes, found
12 benefit cost ratios ranging between 14.9 and 32.5.

13 The HEAT for walking and cycling (Rojas-Rueda et al, 2011; De Hartog et al, 2010; Kahlmeier,
14 2010; WHO, 2014) addressed the question “If x people cycle or walk for y minutes on most
15 days, what is the economic value of the health benefits that occur as a result of the
16 reduction in mortality due to their physical activity?” (WHO, 2014, page 14). It is based on
17 the value of a statistical life and provides a tool to estimate the health benefits in terms of
18 mortality reduction from walking or cycling interventions. Using the HEAT method, Rabl and
19 de Nazelle (2012) found that for a driver who switches to cycling or walking for a commute
20 of 5 km (one way) 5 days/week 46 weeks/year the health benefit from the physical activity
21 is worth about 1,200 €/year, even though it may be questionable whether a person would
22 actually walk 10km/day for commuting purposes.

23 Other studies have used the hedonic price method, focussing on “walkability” – the quality
24 of walking conditions, including safety, comfort and convenience – and how this is affected

1 by development density, land use mix, provision of public open space and pedestrian
2 infrastructure (Cortright, 2009; Sohn et al., 2012). Such studies have found that house
3 prices in more walkable neighbourhoods are about US\$4,000 - US\$34,000 higher than
4 houses located in areas with average levels of walkability.

5 Although the economics of walking may have been relatively overlooked by health
6 economists, it has been extensively investigated in transportation economics and the
7 economics of outdoor recreation. The transportation literature has most commonly used a
8 value of time trade-off method to compare different transportation modes including
9 walking (see Beesley, 1965; Wardman, 1998; Small and Verhoef, 2007). Walking is not a
10 popular transportation mode, unless for very short journeys, and is often only considered in
11 conjunction with a second transportation mode – walking and driving, walking and travelling
12 by bus, or walking and travelling by train – as walking alone is impracticable for longer
13 journeys (Litman, 2003).

14 The economic value of outdoor recreation sites, including walking facilities has been
15 extensively studied, first using a revealed preference method, the travel cost method,
16 (McConnell and Strand, 1981, Bockstael et al, 1987, Herriges and Kling 1999, Abidoye et al,
17 2012) and then using stated preference methods, such as contingent valuation (Bishop and
18 Heberlein, 1979, Hutchinson et al 1999), contingent behaviour (Alberini and Longo, 2006)
19 and choice experiments (Hanley et al, 1998, Adamowicz et al, 1998,). The travel cost model,
20 originally conceived by Hotelling (1949) and developed by Clawson (1959) and Clawson and
21 Knetsch (1976), treats the cost of travel to a site as a proxy for the value of the trip. In the
22 United Kingdom, Christie and Matthews (2003) applied the travel cost model to assess the
23 economic value of outdoor recreation in England and found that walkers in the English
24 countryside spend around £6.14 billion a year, generating a profit in excess of £2 billion and

1 supporting up to 245,000 full time jobs. This literature does not consider health benefits
2 which could have been gauged by the average distance walked and frequency of trips. The
3 contingent valuation method and choice experiments have also been extensively used in the
4 UK to assess the monetary value of hypothetical improvements to walking paths, recreation
5 infrastructure and access to the countryside (Bateman et al, 1996; Christie, 1999; Scarpa et
6 al, 2000a, 2000b; Angus et al, 2006; Morris et al, 2009). This is a well developed literature
7 which has ignored health benefits but often includes information on distance walked and
8 trip frequency.

9 In summary, previous studies have found that walking is affected by land use and built
10 environment infrastructure, and that the walking infrastructure of neighbourhoods is
11 reflected in real estate prices. The non-market value of walking has been studied
12 extensively in both transportation and outdoor recreation studies, including the effect on
13 demand of walking infrastructure (Scarpa et al, 2000a, 2000b), but provides no estimates of
14 the health benefits. So extensive and well developed is this literature in outdoor recreation
15 that there are many meta-analyses intended for benefit transfer purposes which
16 investigate the stability of the relationship between site infrastructure and walking demand
17 across large numbers of sites. For example, Matthews et al (2009) uses data for walking at
18 42 major recreation sites in Ireland and Scotland. Economists of outdoor recreation have
19 also used detailed focus group discussions among walkers and other forest users as pilot
20 studies to determine which attributes of forests users value and while recreation use is
21 often mentioned health benefits have been largely overlooked (Chilton and Hutchinson
22 1999a 1999b and 1999c). In spite of a common interest in modeling walking demand, there
23 is little meeting of minds between this area of environmental economics, where demand
24 analysis is mostly conducted in willingness to pay space, and health economics, which is

1 interested in the demand quantity response for walking, which is directly related to health
2 behavior change. In the next section we present a novel economic model of demand
3 quantity response to improvements in walking infrastructure in a residential
4 neighbourhood, using a revealed preference method that builds on the weak
5 complementary approach of the travel cost model. The travel cost model has been used in
6 very few studies for valuing health benefits, and never for valuing walking (Clarke, 1998;
7 2002; Jeuland et al, 2009). When discussing the application of non-market valuation
8 methods in health economics, Hanley et al (2003) mostly consider stated preferences
9 methods.

10

11 **3. A model for the demand for walking in the neighbourhood**

12 In this paper we are interested in valuing the demand for walking in the neighbourhood,
13 with neighbourhood walking defined as walking in the area of a city where a person also
14 lives. Walking in a neighbourhood is a good not traded in any market. To assess both the
15 demand response and the monetary benefits of transport walking and recreational walking
16 in the local neighbourhood, we rely on a non-market valuation technique, where the quality
17 of a neighbourhood is a non-market or public good (Freeman, 2003.) We assume that
18 people receive private utility from walking in a residential neighbourhood. We further
19 assume ‘weak complementarity’ between walking and a neighbourhood’s pedestrian
20 characteristics: as a neighbourhood becomes more walkable, walking in the neighbourhood
21 increases (Saelens and Handy, 2008; Wilson et al, 2011). This latter assumption allows us to
22 build a utility function that permits us to model changes in a public good – improvement in
23 neighbourhood pedestrian characteristics – and to trace these changes to changes in

1 consumption of a complementary private good – individual walking activity in the
2 neighbourhood. Consider an individual's utility function,

3

$$4 \quad (1) \quad u_i(w_i, \mathbf{N}_i, \mathbf{Z}),$$

5

6 where u_i is utility of individual i , w_i is the number of minutes that individual i walks in
7 his/her neighbourhood in a seven day period, \mathbf{N}_i is a vector of quality attributes of individual
8 i 's neighbourhood, and \mathbf{Z} is a vector of all other goods. Even though walking may be
9 considered a daily activity, we model the amount of walking in a neighbourhood on a
10 weekly basis, to accommodate for the fact that the amount of walking may vary between
11 weekdays and weekends. Individual i 's budget constraint is given by

12

$$13 \quad (2) \quad y_i + a_i = \mathbf{Z} + p_i w_i,$$

14

15 where y_i is income, a_i is individual i 's wealth, and p_i is the opportunity cost of time,
16 expressed in terms of hourly wage, i.e. the price of walking. Maximization of utility subject
17 to the budget constraint yields a system of Marshallian demand functions for walking in the
18 neighbourhood,

19

$$20 \quad (3) \quad w_i = w_i(\mathbf{N}_i, \mathbf{X}_i, p_i, a_i, s_i),$$

21

22 where \mathbf{X}_i is a vector of individual i 's characteristics, such as gender, age, BMI, and s_i is the
23 season when individual i is surveyed. We assume that the demand response for walking is
24 affected by neighbourhood characteristics, hourly wage, and wealth. All else being equal,

1 an improvement in neighbourhood walking characteristics will produce a positive demand
2 response for walking in the neighbourhood, $\frac{dw}{dN} \geq 0$; the more expensive walking in the
3 neighbourhood is, the less people walk in their neighbourhood, $\frac{dw}{dp} \leq 0$; as an individual
4 becomes wealthier, we assume that he/she walks less in his/her neighbourhood, as other
5 more expensive alternatives become available, $\frac{dw}{da} \leq 0$. Walking in the neighbourhood is an
6 inferior good: as an individual becomes wealthier, walking in the neighbourhood should be
7 substituted by more expensive activities, such as cycling, driving, going for a walk at
8 substitutes sites, such as more pleasant and more distant area, or going to a golf course or
9 a gym.

10 To assess the non-market value of walking in the neighbourhood, we recall that the concept
11 of weak complementarity implies that the value of, or the willingness to pay (WTP) for a
12 public good equals the value of access to the private good (Freeman, 2003). The value of
13 walking in a neighbourhood can then be calculated by estimating the Hicksian demand
14 function for walking and then calculating the compensating variation under a hypothetical
15 scenario where no pedestrian access to the neighbourhood is allowed. The compensating
16 variation measures the amount of income paid or received to compensate for an exogenous
17 change in the provision of a good that leaves an individual at the initial level of utility.

18 Equation (3) is the Marshallian demand function, and not the Hicksian demand function. To
19 use the Marshallian demand function, preferences must satisfy the weak complementarity
20 assumption and the "Willig condition" (Willig, 1976), which requires, as described by
21 Bockstael and McConnell (1993), that, at the equilibrium, the effect of a good's price change
22 on the marginal price of quality equals the effect of a quality change on the quantity
23 demanded of the good. In our case, the Willig condition requires that the change in the

1 value of walking given a change in the opportunity cost of time equals the effect of a change
2 in the demand for walking given a change in neighbourhood characteristics. Given these
3 assumptions, we can use the demand function (3) to estimate the quantity and value effects
4 of a quality change in neighbourhood walking characteristics.

5 Equation (3) can be used to calculate two types of monetary values for walking: the access
6 value of all pedestrian use of the neighbourhood and the effect on walking value and
7 distance walked of a change in a characteristic of the neighbourhood. It is this demand
8 response or effect on distance walked which is the primary focus of this paper. The access
9 value is calculated as the area under the demand curve for walking from the current
10 opportunity cost of time p to the minimum level of the opportunity cost of time that induces
11 zero consumption of walking, the so called 'choke price' p^* :

12

$$(4) \text{ WTP}(all\ access) = \int_{p_0}^{p^*} w_i(N_i, X_i, p_i, a_i, s_i) dp_i$$
$$= m(N_i, X_i, p_i^*, a_i, s_i) - m(N_i, X_i, p_i, a_i, s_i),$$

15

16 where m is the expenditure function and p_0 is the current opportunity cost of walking for
17 individual i . Equation (4) is of particular interest to policy makers who want to assess the
18 total economic value of walking in a neighbourhood. This measure is of interest when policy
19 makers have to consider a drastic policy change that could result in a closure of an area for
20 all walking activities, such as the complete removal of pedestrian access.

21 Most often policy makers are interested in valuing the effect on walking of changes in some
22 characteristics of a neighbourhood, the demand response for walking, of infrastructure
23 changes. To value a change in one or several characteristics of a neighbourhood, we
24 estimate the demand curve (3) under current and changed neighbourhood characteristics,

1 and then calculate the compensating variation and change in walking demand for the
2 proposed policy change. For an improvement in a neighbourhood quality to the level N_i^* ,
3 the demand for walking described by equation (3) shifts to the right. The improved welfare,
4 the compensating variation, or the WTP, brought about by the policy change is the area
5 between the two demand curves above p_0 :

$$7 \quad (5) \quad WTP(\Delta \text{ in quality}) = \int_{p_0}^{p^*} w_i^*(N_i^*, X_i, p_i, a_i, s_i) dp_i - \int_{p_0}^{p^*} w_i(N_i, X_i, p_i, a_i, s_i) dp_i$$

8
9 Equation (5) is useful when policy makers want to assess the monetary value of and the
10 demand response to improvements that will affect walking in a neighbourhood by, for
11 example, providing improved walking facilities, making green open spaces more attractive,
12 or making an area safer from crime. Once welfare measures and demand response have
13 been calculated, it is possible to estimate the health benefits associated with additional
14 walking produced by the walking demand response to neighbourhood renewal programs
15 offering improved walking infrastructure. From the point of view of health economics it is
16 the demand response or behaviour change in walking which is of most interest. The welfare
17 measures or WTP may be of primary interest to local government officials who may insist
18 that projects of this type be seen to pass the benefit cost test before infrastructure
19 investments are made.

20

21 **4. Data**

22 The area chosen in this study is the site of a proposed major urban regeneration public
23 sector investment - the Connswater Community Greenway in East Belfast, Northern Ireland,
24 United Kingdom - a the development of a 9 km linear park, including the provision of new

1 cycle paths and walkways. The data were collected through in-person interviews over a 12
2 month period (Feb 2010-Jan 2011), using a random sample of addresses stratified by
3 electoral ward within a 1-mile radius of the Greenway for a total population of 73,378 (Tully
4 et al, 2013). Ethical approval for the study was provided by OREC, Northern Ireland,
5 (Reference, 09/NIR02/66). (See the supplementary material for the survey instrument). In
6 each household, using the last birthday rule, an adult (16 years or older) was interviewed for
7 a final sample of 1,209 respondents. To reduce sample selection bias, interviewers would
8 make at least 3 calls to each address at varying times of the day and evening, and days of
9 the week. Our analysis, after deleting 7 respondents who were unable to walk, is
10 characterized by the following descriptive statistics: 40.6% are male, 30% own a car, 51%
11 are employed and almost 33% are graduates. On average, our respondents are about 50
12 years old, and earn a gross weekly income of £465.73 (At the time of the survey, the
13 exchange rate was about 1GBP(£) = 1.60US\$). Our sample mirrors reasonably well the
14 characteristics of the population of the area, which has a lower proportion of females than
15 our sample. The corresponding statistics for the population of the residents in the wards we
16 surveyed are: female 53%; full time or part time employed 55,9%; average age 39 years (this
17 is computed for the whole population, whilst our sample surveyed individuals older than 16
18 only) (2011 Census).

19 The survey queried respondents about their perceptions of the characteristics of their local
20 neighbourhood, their health status, and the amount of walking they habitually do.

21 Respondents were asked to rate three characteristics of their neighbourhood as either
22 'poor', 'fair' or 'good': 1) safety of the area from crime; 2) availability of walking paths and
23 attractive open spaces; 3) availability of local shops and facilities within walking distance.

24 Results show that neighbourhoods in East Belfast are considered to be relatively safe from

1 crime, as approximately 45% of respondents rate their neighbourhood to have a good level
2 of safety, 43% consider their neighbourhoods' safety to be fair and only about 11% of
3 participants deem their area 'poor' in terms of safety from crime. Our participants also
4 consider their neighbourhood to score quite well in terms of availability of walking paths
5 and attractive open spaces, with almost 80% of respondents judging their neighbourhoods'
6 availability of walking facilities to be either 'good' or 'fair'. Finally, most respondents (72.3%)
7 say that there is a good availability of local shops and facilities within walking distance.
8 Next, we assigned each respondent to an objectively measured walkability index ranging
9 from 1 to 4 (1=Low walkability; 2=low-med; 3=med-high; 4=high). This index is calculated for
10 the neighbourhood where respondents live, based on residential density, street sidewalk
11 intersection density, land use mix, and retail floor area ratio following methods outlined in
12 Leslie et al, 2007 and Frank et al, 2010. The median value for this variable is equal to 2,
13 suggesting that East Belfast is equally split between areas characterized by good walkability
14 and areas with poor walkability.

15 To measure health outcome, we used the EQ-5D-5L standardised instrument, available at
16 www.euroqol.org. Most respondents consider that they enjoy good health, as, on average,
17 they report their health status to be equal to 73, on a 1 to 100 scale, where 1 means very
18 poor, and 100 excellent. Despite this data, our sample confirms the prevalence of obesity in
19 Northern Ireland, as most of our respondents are either overweight (36%) or obese (20%),
20 and the median (self reported) BMI is equal to 25.84.

21 Respondents were instructed to consider the amount of time they spend walking to and
22 from places such as work, shops and places of worships and for recreational purposes. They
23 were first asked about how much time they spent walking in a typical week at this time of
24 the year. Next, they were asked about how much of that time they spent walking in their

1 neighbourhood. The first question on walking aims at making the respondent think about all
2 the walking he/she usually does, and at assessing any substitutes for walking in a
3 respondent's neighbourhood. The second question is the one of interest to us, as this
4 question allows us to assess the amount of walking in a person's neighbourhood. Thus over
5 a seven day period, the median respondent reports walking 150 minutes. Of these, 100
6 minutes are spent walking in his/her local neighbourhood. From these answers we notice
7 that half of our sample currently does less than the recommended amount of physical
8 activity. To account for any substitutes for walking, respondents reported the amount of
9 moderate intensity physical activity per day, which on average is about 28 minutes per
10 respondent. Descriptive statistics for our sample are reported in Table 1.

11

12

1 Table 1. Descriptive statistics

Variables	N	Mean	Std Dev	Minimum	Maximum	Median
Walkab (objective measure of walkability: 1=Low walkability; 2=low-med; 3=med-high; 4=high)	1192	2.42	1.12	1	4	2
BMI	1137	26.52	5.53	15.06	57.47	25.84
age	1185	50.29	18.94	16	94	49
income	1038	465.73	388.90	90	1500	340
health (1=very poor; 100=excellent)	1198	73.77	19.65	3	100	80
In a typical day, how many minutes do you spend doing moderate-intensity physical activity?	1202	28.40	55.19	0	420	0
G1 In a typical week at this time of year how much time do you spend walking? (MINUTES)	1202	243.64	319.30	0	3300	150
G2 And how much of that time do you spend walking in your local neighbourhood? (MINUTES)	1202	175.35	247.03	0	2400	100
Dummy variables (N=1202)						Mean
walkab_miss (dummy variable for missing 'walkability')						0.0083
BMI_miss (dummy variable for missing 'BMI')						0.0541
age_miss (dummy variable for missing 'age')						0.0141
income_miss (dummy variable for missing 'income')						0.1364
health_miss (dummy variable for missing 'health')						0.0033
crime_good (equals to 1 when safety of the area from crime is good)						0.4509
walk_good (equals to 1 when availability of walking paths and attractive open spaces is good)						0.4318
shop_good (equals to 1 when availability of local shops and facilities within walking distance is good)						0.7230
Male (equals to 1 when a respondent is male)						0.4060
Degree (equals to 1 if a respondent has at least a graduate degree)						0.3278
Couple (equals 1 if a respondent is married or living with a partner)						0.4991
Car (equals to 1 if a respondent has at least one car in the household)						0.2920
Spring (equals to 1 if a respondent was surveyed in Spring)						0.1963
Summer (equals to 1 if a respondent was surveyed in Summer)						0.1988
Autumn (equals to 1 if a respondent was surveyed in Autumn)						0.2471
Winter (equals to 1 if a respondent was surveyed in Winter)						0.3577

2

3 **5. Econometric Analysis**

4 To model the demand for walking, we use a tobit model (Tobin, 1958) to account for the
 5 fact that time spent walking is either positive or zero. We estimate the following regression
 6 model based on equation (3):

7

1 (6) $w_i = Y_i\beta_y + \varepsilon_i$,

2

3 where w_i is the number of minutes walked in the neighbourhood in a seven day period by
4 respondent i ; Y is a vector comprising an intercept, neighbourhood characteristics,
5 respondent's i characteristics, including a variable that captures the value of time,
6 calculated as 15% of the net weekly income, divided by the number of minutes worked; β_y
7 is a vector of coefficients to be estimated; ε_i is an error term assumed to be independently
8 and normally distributed with mean zero and variance σ^2 . Table 2 reports the output of
9 three specifications for the tobit model. We favour the use of a tobit model because the
10 data for time spent walking conform to a 'corner solution model', being either zero or
11 positive, as indicated by Wooldridge (2002). Using ordinary least squares would result in
12 inconsistent parameter estimates. An alternative model would be to apply a Cragg model, a
13 two stage model where first a dichotomous choice model estimates the decision to
14 participate in walking and then a truncated model is estimated on the assumption that
15 when an individual decides to participate, the quantity of walking is positive. One of the
16 difficulties in using a two-step model, like the Cragg model, would be in deciding which
17 variables to use to explain the decision to participate. In addition, a Cragg model would
18 underestimate the demand responsiveness, as much of this would be captured by the
19 decision to participate.

20 In Table 2, Model (1), we use only an intercept, walkability (walkab), that ranges from 1 to 4
21 (1=Low walkability; 4=high walkability) and a dummy variable (walkab_miss) as explanatory
22 variables. To circumvent the problem of missing values in some of our independent
23 variables, we recode an independent variable to zero when missing and create a dummy
24 variable, that takes on a value of one when the independent variable is missing and zero

1 otherwise, and entering both the recoded independent variable and the indicator of a
2 missing value in the right-hand side of the equation (Longo and Alberini, 2006). Variables for
3 which we have missing observations are: walkab, BMI, age, income and health. We find that
4 walkability is positive and significant, suggesting that the more objectively 'walkable' an
5 area is, the more time people spend walking. The variable 'walkab_miss' is not statistically
6 significant, indicating that respondents for whom we have no information about the
7 walkability of their area are not different in terms of amount of walking from respondents
8 for whom we do have information on the walkability of their area. We look at the effects of
9 other variables in the next specification.

10 The second specification, Table 2, Model (2), investigates the effects on walking of
11 respondents' subjective perceptions of the walkability of the area, in addition to the
12 objective walkability measure, by studying the effect of (a) safety of the area from crime, (b)
13 availability of walking paths and attractive open spaces, and (c) availability of local shops
14 and facilities within walking distance, as perceived by the respondents. The results show
15 that walking is positively affected by the presence of shops and facilities at walking distance,
16 whilst the safety of the area and the availability of walking paths and attractive open space,
17 as perceived by respondents do not affect time spent walking.

18

19

- 1 Table 2. Tobit model. Dependent variable is minutes walked in the neighbourhood in a
- 2 seven day period.

	Model 1		Model 2		Model 3		Model 4	
	Coeff.	t-ratio	Coeff.	t-ratio	Coeff.	t-ratio	Coeff.	t-ratio
Constant	60.84	2.98	17.56	0.68	-55.99	-0.64	-56.84	-0.66
Crime_good			-23.31	-1.26	-19.19	-1.05	-14.95	-0.82
Walk_good			19.98	1.02	16.97	0.87	20.46	1.06
Shop_good			66.81	3.21	52.40	2.50	52.80	2.53
Walkab	32.46	4.28	31.04	3.96	28.55	3.61	22.45	2.78
Walkab_miss	58.09	0.69	53.59	0.56	64.13	0.68	42.71	0.46
BMI					-2.84	-1.74	-2.70	-1.66
BMI_miss					-1.32	-0.02	-1.85	-0.03
Male					15.07	0.87	18.86	1.10
Age					0.11	0.04	1.77	0.66
Age_squared					-0.01	-0.55	-0.03	-1.32
AGE_miss					-35.24	-0.37	-9.85	-0.10
Spring					73.49	3.11	68.28	2.88
Summer					104.13	4.43	96.08	4.08
Autumn					56.27	2.55	54.81	2.50
Health					1.86	4.14	2.06	4.56
Health_miss					105.94	0.67	107.35	0.68
Substitute							0.02	0.41
Car							-50.17	-2.46
Income							-0.03	-1.65
Income_miss							-59.50	-0.30
Sigma	286.44	42.69	284.95	42.73	278.46	42.83	276.92	42.83
Observations	1202		1202		1202		1202	
Log-likelihood	-7062.37		-7054.781		-7022.60		-7016.94	
AIC	11.75		11.75		11.71		11.71	
BIC	11.77		11.78		11.79		11.80	

3

1 The third specification in Table 2, Model (3), adds respondents' socio economic
2 characteristics, in addition to the 'walkability' index of the area and respondents'
3 perceptions about the quality of their neighbourhood. We find that the higher the BMI and
4 the poorer the health, the less a respondent walks. Walking does not appear to differ with
5 age and gender. Walking is lowest in winter (reference dummy), increases in spring, peaks in
6 summer, and declines in autumn.

7 In the fourth specification, Table 2, Model 4, we add variables for respondents' income, car
8 ownership and minutes of walking in a different area to a respondent's neighbourhood,
9 calculated as the total amount of walking minus the amount of walking in a respondent's
10 neighbourhood, which aims to capture the effect of substitute opportunities for walking.

11 Similarly, the variable 'car', captures both a measure of wealth, as well as a substitution
12 possibility for walking as a mode of transport. A log-likelihood ratio test shows that model 4
13 outperforms model 3 at the 5% level (Chi-squared is equal to 11.32, with 4 degrees of
14 freedom). This specification confirms the findings of previous specifications: walking

15 increases with an increase in the objective walkability of an area, with the increased supply
16 of shops and facilities at walking distance, with the good health of a respondent and

17 decreases with an increase in BMI. In addition, we find that whilst walking in a

18 neighbourhood is not affected by how much a person walks elsewhere, owning a car

19 reduces the amount of walking. We also find a negative and significant coefficient for

20 income, suggesting that walking in a person's neighbourhood is an inferior good: the higher

21 the salary, the less a person walks in her/his neighbourhood. In specifications not reported

22 here, we investigated any spatial effects by running cluster regression models (Wooldridge,

23 2001), using dummy variables for the wards where residents live, but found the coefficients

24 of the cluster dummy variables to be not statistically significant.

1

2 **6. Demand Response and welfare analysis for improved walking infrastructure**

3 We use the results of Model 4 to calculate the marginal effects on walking, reported in

4 Table 3:

5

6
$$(7) \frac{\partial E[w_i|y_i]}{\partial y_i} = \beta \Phi \left(\frac{y_i' \beta}{\sigma} \right)$$

7

8 Table 3. Marginal effects (minutes of walking per week)

	Marginal effect	Std.
Shop_good	36.48	14.40
Walkab	15.51	5.58
BMI	-1.86	1.12
Spring	47.18	16.37
Summer	66.38	16.28
Autumn	37.87	15.17
Health	1.42	0.31
Car	-34.67	14.08
Income	-0.02	0.01

9

10 Respondents rating their area as having ‘good’ availability of shops and facilities in their
11 neighbourhood walk on average 36.48 minutes (std. err. 14.40) more per week compared to
12 people who live in areas rated as having poor or fair availability of shops and facilities at
13 walking distance. This also means that improving an area’s availability of shops and facilities
14 improves walking by more than half an hour per week. Car ownership decreases the walking
15 in an area by 34.7 minutes (std. err.14.08) per week, suggesting that policies that increase
16 the cost of car ownership or car usage may have an important effect on the amount of
17 physical activity that people do. Interventions that improve the objective walkability of an
18 area lead to an increase in walking of about a quarter of an hour per week. The table also

1 shows strong seasonality in walking patterns: in summer people walk about one hour and 6
 2 minutes more than in winter, a result that is consistent with previous literature (Tucker and
 3 Gilliland, 2007).

4 We use model (4) and equations (4) and (5) to calculate the demand response and monetary
 5 value of improved walking infrastructure in the neighbourhood. Using equation (6),
 6 considering that the 'choke price', p^* , is the price that sets the demand for neighbourhood
 7 walking to zero, equation (4) becomes:

$$9 \quad (8) \quad WTP(access) = \int_{p_0}^{p^*} \mathbf{Y}_i \boldsymbol{\beta}_y dp_i = -\frac{\hat{w}^2}{\beta_p},$$

10

11 where \hat{w} is the predicted number of minutes walked per week from equation (4) and model
 12 (3). Using equation (8), the access value to walking in the neighbourhood is equal to £33.27
 13 (std. err.20.21, calculated with the delta method) per week. This is the monetary value that,
 14 on average, a person living in East Belfast values the right of access to walking in the
 15 neighbourhood.

16 The access value is, however, of limited interest, as it is unlikely that a neighbourhood
 17 becomes unavailable for walking. More interesting is an assessment of the monetary value
 18 and especially the supply response to interventions aimed at improving the walkability of
 19 the area. To value a change in one or several characteristics of a neighbourhood, we use
 20 model (4) and equations (5) and (8) under current and changed neighbourhood
 21 characteristics:

22

$$23 \quad (9) \quad WTP(\Delta \text{ in quality}) = \int_{p_0}^{p^*} \mathbf{Y}_i^* \boldsymbol{\beta}_y dp_i - \int_{p_0}^{p^*} \mathbf{Y}_i \boldsymbol{\beta}_y dp_i = -\frac{\hat{w}^{*2}}{\beta_p} + \frac{\hat{w}^2}{\beta_p},$$

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Where Y_i^* is the demand for walking under improved neighbourhood characteristics, and \hat{w}^* is the predicted number of minutes spent walking – the demand response for walking – in a seven day period estimated from model (3) and (6) under improved neighbourhood characteristics. For example, a policy that improved East Belfast walkability from the current levels to the ‘high’ level of walkability throughout the district and that also improved people’s perceptions of their areas from the current levels to ‘good’ levels in terms of availability of local shops and facilities within walking distance would result in an increase of walking for the average respondent of 36.18 minutes (std. err. 9.93) per week. Such a policy is valued at £13.65 (std. err. 9.49) per week. Table 4 reports a set of demand responses for walking and related monetary values for selected scenarios.

Table 4. Increased minutes of walking per week and monetary value of (WTP) in GBP (£) for selected scenarios. Standard errors calculated with the Delta Method.

Scenario	WTP (std. err.)	Increased minutes of walking (std. err.)
Improving East Belfast to high walkability; good availability of local shops and facilities within walking distance; all other variables at their mean value	13.65 (9.49)	36.18 (9.93)
Improving East Belfast’s availability of local shops and facilities within walking distance to ‘good’; all other variables been at the average value	3.62 (2.63)	10.24 (4.09)
Improving East Belfast’s walkability to ‘high’; all other variables been at the average value	9.30 (6.98)	25.31 (9.38)
Respondent interviewed in spring with BMI=23, gross weekly income=500, health status=85, no car for improving East Belfast to ‘high’ walkability and ‘high’ availability of local shops and facilities within walking distance	18.13 (13.00)	39.96 (10.89)
Respondent interviewed in spring, BMI=32, gross weekly income=500, health status=55, no car; improving East Belfast to ‘high’ walkability and ‘high’ availability of local shops and facilities within walking distance	12.12 (8.74)	34.94 (8.74)

1 We notice the differences between normal weight and obese respondents, with the latter
2 having a considerably lower value for improvements in their neighbourhood and also a
3 lower increase in expected walking. For example, a policy that improves the walkability to
4 'high' and also improves people's appreciation of the availability of shops and facilities at
5 walking distance to 'good', leads to an increase of almost 40 minutes per week of walking
6 for a respondent with a health status of 85 and BMI of 23, and of only 35 minutes for a less
7 healthy respondent with a health status of 55 and a BMI of 32. Although obese people walk
8 at a slower speed (Browning and Kram, 2005), they would accumulate a similar amount of
9 energy expenditure from 35 minutes of walking - 170 kcals if walking at 3.0 Metabolic
10 Equivalent of Task (METs) - compared to the normal weight individual walking for 40
11 minutes - 164 kcals if walking at 3.5 METs - assuming they were both of similar height (1.7m
12 in this example) (Bushman, 2011).

13

14 **7. Discussion and conclusion**

15 Walking in the area where a person lives is a widely accessible form of moderate-intensity
16 physical activity, suitable for overweight and obese people, as well as for older people with
17 limited mobility or limited transport opportunities, who are less likely to perform vigorous-
18 intensity physical activity. Walking has been found to improve human health by reducing the
19 development of cardiovascular diseases and cancer. Given its importance, it is surprising
20 that there has been little health economic research into modelling the demand response
21 which is linked to behaviour change. In this paper we have introduced a novel revealed
22 preference model of the demand response for walking and the enhanced value of
23 neighbourhood walking which results from improvements in neighbourhood walkability and

1 walking infrastructure. The model assumes that walking in a neighbourhood depends on the
2 characteristics of the neighbourhood, as well as residents' characteristics. We have found
3 that walking in the area where a person lives is an "inferior" good: as an individual becomes
4 wealthier, walking in the neighbourhood will be substituted with more expensive activities,
5 such as cycling, driving, walking in a different area outside the neighbourhood, or going to
6 the golf course and the gym. To our knowledge, this is the first time that such a model has
7 been proposed for estimating the demand response, the potential health benefits and
8 consumer's value of walking. We have applied the model to walking in East Belfast,
9 Northern Ireland, UK, and find that our empirical data supports our theoretical model:
10 minutes walked are negatively affected by the value of time and by a person's wealth. We
11 further find that people living in more walkable areas and in areas which have a good
12 availability of local shops and facilities within walking distance, tend to report walking more
13 than other people.

14 Considering the monetary value of walking, a public programme that would enhance to a
15 'high' level the walkability of all of East Belfast and improve to 'good' all resident's
16 perception of the availability of local shops and facilities within walking distance is valued at
17 £13.65 (std. err. 9.49) per person per week. Assuming that estimated levels would
18 correspond to actual behaviours, the corresponding increase in minutes walked per week
19 from such a policy should result in 36.18 (std. err. 9.93) extra minutes walked per person on
20 average. These results show that a policy that would produce an increase of about one
21 quarter of the recommended amount of moderate-intensity physical activity has an average
22 annual value per resident of about £710. When we apply the WHO's HEAT methodology
23 (WHO, 2014) to our data, using a value of a statistical life for the UK of £3.2M, and a
24 mortality rate of 432.1 deaths per 100,000 people per year, we find that the same policy

1 would be worth about £34 per resident per year. This is a much lower estimate than the one
2 arising from our model, suggesting that the WHO's HEAT methodology underestimates the
3 total value of walking, as it only focuses on the health benefits of walking from mortality risk
4 reduction.

5 One may wonder whether individuals who like walking may decide to live in more walkable
6 areas. To address this point, we investigate any difference in walking outside an individual's
7 neighbourhood. Using a t-test, we find no difference (p -value=0.93279) in mean values for
8 walking outside an individual's neighbourhood for people living in high walkability areas
9 (walkab = 3 or 4) and for people living in low walkability areas (walkab = 1 or 2). From this
10 result, it appears that people walk more in more walkable areas because they live in those
11 areas, and not because they walk more in general. Future longitudinal studies should cast
12 more light on this issue.

13 From a policy perspective, it may be interesting to investigate the effects on inactive
14 residents, to gauge the impact on the numbers becoming active and reaching the
15 recommended guidelines of 150 minutes per week of moderate-intensity physical activity.
16 When we focus our attention on inactive participants, respondents who currently do not
17 engage in at least 30 minutes of moderate-intensity physical activity per day, and walk less
18 than 150 minutes per week, we find that this group of 567 respondents (about 44% of our
19 survey sample) only walks a total of 105 minutes per week on average. These are
20 respondents with an average BMI of 25.40, are on average 53 years old, predominantly
21 female (62%), with a self-reported health value of 68.5, and a weekly income of £373. Our
22 demand response model shows that if the government implemented a public program to
23 maximize the walkability of East Belfast and to improve residents' perceptions of the
24 attractiveness of the area, then these inactive respondents would, on average, increase

1 their amount of walking by 38.49 minutes (std. err. 10.25) per week. Such a program would
2 therefore increase, on average, the total amount of moderate-intensity physical activity for
3 this group of inactive residents to about 142 minutes per week, an increase of about 35%,
4 an important amount, though still short of the recommended 150 minutes per week. Put
5 another way, this policy would help an additional 12.8% of the inactive sample (73 people) -
6 who do not currently meet the recommended guidelines for physical activity – achieve the
7 recommended target of 150 minutes per week of physical activity. Interestingly, when we
8 look at the average characteristics of these 73 respondents, we find that this is a relatively
9 young group, about 47 years old, with a large proportion of men, 44%, with a BMI of 24.7, a
10 self-reported health status value of 75, and a weekly income of £421, a healthier (and
11 wealthier) group compared to those not achieving the recommended targets for physical
12 activity after the implementation of the walkability improvements.

13 Additional interventions would therefore be needed to encourage inactive residents to
14 achieve the recommended levels of physical activity, as it appears that interventions that
15 improve the walkability of an area are particularly effective in increasing walking among
16 already active citizens, and, among the inactive ones, the best response is found among
17 those healthier, younger and wealthier citizens. Sattelmair et al. (2011) have shown that
18 compared to taking no physical activity, people who are physically active at half the
19 recommended level (75 minutes per week), are at a 14% lower risk of coronary heart
20 disease. Our findings of a possible increase of nearly 30 minutes on average per week of
21 activity from infrastructure and walkability changes to the neighbourhood may therefore be
22 associated with widespread health benefits. Compared with completely inactive adults,
23 Wen et al (2011) have demonstrated that those who undertake low levels of activity (90
24 minutes per week), had a 14% reduced risk of all-cause mortality, and had a 3 year longer

1 life expectancy. After that, every additional 15 minutes of activity (half the level we have
2 demonstrated) further reduced all-cause mortality by 4% and all-cancer mortality by 1%.
3 These benefits were applicable to all age groups and both sexes. Considering the results of
4 these studies in conjunction with our findings, we conclude that a policy that improved the
5 walkability in East Belfast to a high level and also improved to 'good' residents' perceptions
6 of the availability of local shops and facilities within walking distance, would contribute to
7 an increase in moderate-intensity physical activity of about 36 minutes on average per
8 week, which could result in a reduced all-cause mortality by about 8% and all-cancer
9 mortality by about 2%.

10 Capewell and Graham (2010) and the recent guidelines from the National Institute for
11 Health and Care Excellence (NICE, 2010) have highlighted how population level measures
12 are generally more effective at narrowing inequalities than interventions targeted at
13 individuals, which may widen inequalities. Our findings demonstrated that for poorer
14 respondents it is relatively less costly to do physical activity in their neighbourhood than
15 elsewhere. However, we also found that an intervention that improves the walkability and
16 the subjective perceptions of the walkable environment where people live is more effective
17 in increasing physical activity levels of already healthy (and wealthier) people. It is therefore
18 vital that we are never seduced by our assumptions (about whole population approaches)
19 and that all public health programmes are evaluated appropriately to mitigate any potential
20 for intervention generated inequalities (Frohlich and Potvin, 2008). One must also be
21 mindful that there are likely to be synergies between physical and social infrastructure (Diez
22 Roux and Mair, 2010) and that changes in social norms (around walking) may also change
23 individual's utility functions (Prior et al 2014) and that even this might have a differential
24 effect across socioeconomic groups.

1 Our conclusions must be guarded, as the analysis is obviously subject to assumptions
2 concerning the relationship between *revealed* and *actual* behaviour which can be tested
3 more robustly by natural field observations after an urban regeneration has taken place. In
4 addition, our WTP perspective might be thought of as providing a lower bound to the
5 monetary benefits to the public sector of such walking infrastructure improvements. It does
6 not include indirect benefits that might arise from improved business and tourism in areas
7 with improved infrastructure, and reduced pollution.

8 Information on the monetary health benefits of walking may also be useful to policymakers
9 since there has been considerable debate about the use of incentives for behavioural
10 change. We found that individuals with a greater BMI have lower values for walking in their
11 neighbourhood and, when compared to people with lower BMI, are likely to change their
12 physical activity levels less under the various improvement scenarios. Therefore, it could be
13 that differential incentives may be required to improve physical activity levels. Larger
14 incentives may be needed to modify the behaviour of individuals with higher BMI values, a
15 suggestion that accords with previous research (Ogilvie, 2007), but which needs to be
16 empirically tested.

17 Our research finds that in Belfast, at least, people do not seem to be walking for health
18 reasons alone, they walk "opportunistically", that is, to reach a destination to undertake
19 regular daily activities such as shopping, eating out, going to places of worship etc., while
20 other physical activities seem to be associated with more moderate-intensity and vigorous-
21 intensity activities such as going to the gym, playing sports etc. This is entirely borne out by
22 the findings of our recent qualitative work with stakeholders of the Connswater Community
23 Greenway (Prior et al, 2014). From these findings we derive two messages for policy
24 makers: 1) walkability is increased by the placing of typical urban structures and functions

1 such as shops, restaurants, libraries and playgrounds within walking distance of as many
2 people as possible, and 2) ordinary walking is a healthy activity and this includes all walking-
3 not just walking for long periods, at a very fast pace or hiking.

4 As a methodological contribution to the literature, this paper has used a novel revealed
5 preferences method to model the demand and value of neighbourhood walking in the event
6 of interventions to improve pedestrian infrastructure in the district. Further research should
7 explore the use of *stated* preferences, also in conjunction with revealed preferences, to
8 investigate the benefits of walking and other forms of physical activity. Stated preferences
9 may be used to further validate the findings from revealed preferences, and/or to explore
10 scenarios that cannot be studied with revealed preferences alone.

11

12

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