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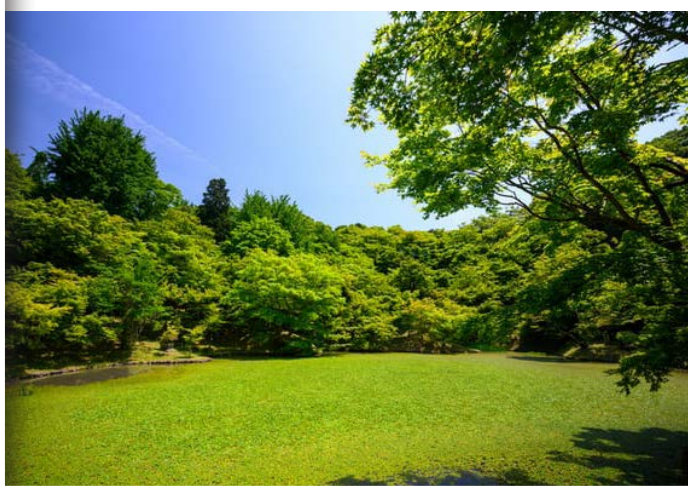
Research on the Environment, Health, Consumer Behaviour and the Economy: ESRI Environment Research Programme 2018-2020

Editor: Anne Nolan. Authors: Achim Ahrens, Peter Barlow, Brian Broderick, Philip Carthy, Aoife Donnelly, Tom Gillespie, Martina Hennessy, Ronan Lyons, Seán Lyons, Pete Lunn, Ciarán Mac Domhnaill, Finn McLaughlin, Stefano Meneto, Frank Moriarty, Owen Naughton, Anne Nolan, Aonghus O´Domhnaill, Margaret O'Mahony, Deirdre Robertson, Iulia Siedschlag, Shane Timmons, Manuel Tong Koecklin and Weijie Yan



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Rialtas na hÉireann
Government of Ireland

ENVIRONMENTAL PROTECTION AGENCY

The Environmental Protection Agency (EPA) is responsible for protecting and improving the environment as a valuable asset for the people of Ireland. We are committed to protecting people and the environment from the harmful effects of radiation and pollution.

The work of the EPA can be divided into three main areas:

Regulation: *We implement effective regulation and environmental compliance systems to deliver good environmental outcomes and target those who don't comply.*

Knowledge: *We provide high quality, targeted and timely environmental data, information and assessment to inform decision making at all levels.*

Advocacy: *We work with others to advocate for a clean, productive and well protected environment and for sustainable environmental behaviour.*

Our Responsibilities

Licensing

We regulate the following activities so that they do not endanger human health or harm the environment:

- waste facilities *(e.g. landfills, incinerators, waste transfer stations)*;
- large scale industrial activities (*e.g. pharmaceutical, cement manufacturing, power plants)*;
- intensive agriculture *(e.g. pigs, poultry)*;
- the contained use and controlled release of Genetically Modified Organisms *(GMOs)*;
- sources of ionising radiation *(e.g. x-ray and radiotherapy equipment, industrial sources)*;
- large petrol storage facilities;
- waste water discharges;
- dumping at sea activities.

National Environmental Enforcement

- Conducting an annual programme of audits and inspections of EPA licensed facilities.
- Overseeing local authorities' environmental protection responsibilities.
- Supervising the supply of drinking water by public water suppliers.
- Working with local authorities and other agencies to tackle environmental crime by co-ordinating a national enforcement network, targeting offenders and overseeing remediation.
- Enforcing Regulations such as Waste Electrical and Electronic Equipment (WEEE), Restriction of Hazardous Substances (RoHS) and substances that deplete the ozone layer.
- Prosecuting those who flout environmental law and damage the environment.

Water Management

- Monitoring and reporting on the quality of rivers, lakes, transitional and coastal waters of Ireland and groundwaters; measuring water levels and river flows.
- National coordination and oversight of the Water Framework Directive.
- Monitoring and reporting on Bathing Water Quality.

Monitoring, Analysing and Reporting on the Environment

- Monitoring air quality and implementing the EU Clean Air for Europe (CAFÉ) Directive.
- Independent reporting to inform decision making by national and local government *(e.g. periodic reporting on the State of Ireland's Environment and Indicator Reports)*.

Regulating Ireland's Greenhouse Gas Emissions

- Preparing Ireland's greenhouse gas inventories and projections.
- Implementing the Emissions Trading Directive, for over 100 of the largest producers of carbon dioxide in Ireland.

Environmental Research and Development

- Funding environmental research to identify pressures, inform policy and provide solutions in the areas of climate, water and sustainability.

Strategic Environmental Assessment

- Assessing the impact of proposed plans and programmes on the Irish environment *(e.g. major development plans)*.

Radiological Protection

- Monitoring radiation levels, assessing exposure of people in Ireland to ionising radiation.
- Assisting in developing national plans for emergencies arising from nuclear accidents.
- Monitoring developments abroad relating to nuclear installations and radiological safety.
- Providing, or overseeing the provision of, specialist radiation protection services.

Guidance, Accessible Information and Education

- Providing advice and guidance to industry and the public on environmental and radiological protection topics.
- Providing timely and easily accessible environmental information to encourage public participation in environmental decision-making *(e.g. My Local Environment, Radon Maps)*.
- Advising Government on matters relating to radiological safety and emergency response.
- Developing a National Hazardous Waste Management Plan to prevent and manage hazardous waste.

Awareness Raising and Behavioural Change

- Generating greater environmental awareness and influencing positive behavioural change by supporting businesses, communities and householders to become more resource efficient.
- Promoting radon testing in homes and workplaces and encouraging remediation where necessary.

Management and structure of the EPA

The EPA is managed by a full time Board, consisting of a Director General and five Directors. The work is carried out across five Offices:

- Office of Environmental Sustainability
- Office of Environmental Enforcement
- Office of Evidence and Assessment
- Office of Radiation Protection and Environmental Monitoring
- Office of Communications and Corporate Services

The EPA is assisted by an Advisory Committee of twelve members who meet regularly to discuss issues of concern and provide advice to the Board.

EPA RESEARCH PROGRAMME 2014–2020

Research on the Environment, Health, Consumer Behaviour and the Economy: ESRI Environment Research Programme 2018–2020

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Editor:

Anne Nolan

Authors:

Achim Ahrens, Peter Barlow, Brian Broderick, Philip Carthy, Aoife Donnelly, Tom Gillespie, Martina Hennessy, Ronan Lyons, Seán Lyons, Pete Lunn, Ciarán Mac Domhnaill, Finn McLaughlin, Stefano Meneto, Frank Moriarty, Owen Naughton, Anne Nolan, Aonghus O´Domhnaill, Margaret O'Mahony, Deirdre Robertson, Iulia Siedschlag, Shane Timmons, Manuel Tong Koecklin and Weijie Yan

ENVIRONMENTAL PROTECTION AGENCY
An Ghníomhaireacht um Chaomhnú Comhshaoil
PO Box 3000, Johnstown Castle, Co. Wexford, Ireland

Telephone: +353 53 916 0600 Fax: +353 53 916 0699
Email: info@epa.ie Website: www.epa.ie

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This report is based on research carried out/data from July 2018 to June 2020. More recent data may have become available since the research was completed.

The EPA Research Programme addresses the need for research in Ireland to inform policymakers and other stakeholders on a range of questions in relation to environmental protection. These reports are intended as contributions to the necessary debate on the protection of the environment.

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Project Partners

Anne Nolan
Economic and Social Research Institute
Whitaker Square
Sir John Rogerson's Quay
Dublin
Ireland
Tel.: + 353 (0)1 863 2022
Email: anne.nolan@esri.ie

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Executive Summary

Continuing the partnership established between the Economic and Social Research Institute (ESRI) and the Environmental Protection Agency (EPA) in phase I (2016–2018) of the programme, this report summarises the findings from the second phase of the programme (2018–2020). A diverse set of research topics was examined, broadly grouped under five thematic areas.

Examining the Impact of the Environment on Health and Wellbeing

The influence of environmental conditions on health was examined using a spatially linked survey and environmental data in three studies.

1. *Walkable green spaces and obesity.* Living in an area with the lowest amount of urban green space, as measured within a 1600 m footpath-accessible network buffer, was associated with a slightly higher body mass index (BMI) in those aged 50 and over. However, no association was found related to other characterisations of walkable green space.
2. *Local air pollution and asthma.* Living in an area with higher nitrogen dioxide concentrations was associated with an increase in the probability of reporting an asthma diagnosis and/or using asthma medication in those aged 50 and over.
3. *Objective and subjective green space*. Relative to those living in rural areas, those with the least amounts of urban green space were more likely to report an open space problem, as were those who reported problems with service provision, safety and cleanliness in their local area.

Characteristics of Biodiversity Data Recorders

In partnership with the National Biodiversity Data Centre (NBDC), data from a specially designed online questionnaire showed that biodiversity data recorders were more socioeconomically advantaged, environmentally aware and physically active, but more likely to have depression, than the general population. A follow-up survey in late 2020 will examine whether or not participation in biodiversity recording activities has any effects on health and wellbeing.

Using Behavioural Science to Design and Test Behaviourally Informed Regulatory Communications

Two studies employed techniques from behavioural science to design and test regulatory communications for use by the EPA:

1. *Testing for radon in high-risk areas*. The first study will use a randomised controlled trial (RCT) to examine how to increase uptake of radon testing. The trial (postponed on account of the coronavirus disease 2019 – COVID-19 – pandemic) will test three manipulations of the standard letter issued to residents in high radon risk areas (envelope design, simplification, personalisation).
2. *Framing strategies for pollution communication*. The second study used a controlled experimental approach to identify general framing strategies for pollution communications. The results suggest that communications should emphasise the role of regulations in protecting the environment and preventing related harms to people, rather than other moral appeals (e.g. to respect the local area).

Examining the Drivers and Consequences of Green Innovations and Green Investments

Using firm-level data, four studies were carried out under this theme.

1. *The effects of environmental regulations on the propensity of firms to introduce green innovations*. The results indicated that environmental regulations incentivised firms to introduce green innovations. Other major drivers included in-house research and development activity, investment in tangible and intangible assets, and firm size.
2. *Do green innovations improve firms' export performance?* Green innovations with benefits for the consumer and product innovations with environmental benefits were positively associated with firms' export participation.

3. *Factors that influence firms' decisions to spend on environmental protection*. The results indicated that larger firms, importers and firms that were part of an enterprise group were more likely to invest in equipment for pollution control and in equipment linked to cleaner technologies.
4. *The effects of green investments on firm performance*. The results showed that, in the medium term, green investments had positive effects on firms' performance. The effects were stronger for firms that were larger, foreign owned, more productive and in low-tech industries.

Land Use and Spatial Planning Issues

The final two studies focused on land use and spatial planning issues.

1. *Urban Rents and Commuting*. A positive relationship between the difference in rents between pairs of areas and the commuting time between them was found, consistent with the idea that high housing costs tend to push those working in urban areas into commuting greater distances.
2. *Value of Urban Green Space*. This study examined the impact that urban green space amenities have on the sale price of housing in Dublin during the period 2010–2018. The results showed a positive price premium for dwellings in the vicinity of parks, implying a capitalised value of approximately €3.4 billion in 2019.

1 Introduction

The Environmental Protection Agency (EPA)/Economic and Social Research Institute (ESRI) Environment Research Programme brings together a diverse set of research topics with the objective of assessing the ways in which the environment interacts with economic and social processes. The programme has at its core the ambition to produce fast and focused policy-relevant analyses that employ publicly available data in new ways and through the generation of policy-relevant behavioural insights. Lyons (2019) provides a detailed summary of the topics examined in the first phase of the programme, which covered the period 2016–2018. In this report we synthesise the results from the second phase of the programme, which comprised 12 studies, carried out between 2018 and 2020. These studies can be grouped into five broad themes:

1. examining the impact of the environment on health and wellbeing;
2. characteristics of biodiversity data recorders;
3. using behavioural science to design and test behaviourally informed regulatory communications;
4. examining the drivers and consequences of green innovations and green investments;
5. investigating land use and spatial planning issues.

These research topics were selected through a process of dialogue with the EPA. In some cases, for example on the health and environment theme, the work further developed the research carried out in phase I. Other themes, for example research on green innovations and green investments, involved entirely new research, using new data sources and methods. Throughout, as in phase I, the partners sought to identify research questions and themes that offered both policy relevance and scope for robust empirical analysis.

It is worth summarising the diversity of data and methodological approaches used in the research programme, as it highlights the uses of different approaches for policy analysis and development.

First, by combining individual-level survey data with administrative data on environmental conditions, we can better understand the impact of environmental conditions on health and wellbeing. This approach allows us to identify inequalities in environmental exposures across the population (e.g. in access to green space, air pollution) and to assess the implications of these environmental conditions for health and wellbeing. In this phase of the programme, we continued to use survey data from the Irish Longitudinal Study on Ageing (TILDA) and we also obtained access to a survey of the adult population aged 15 and over, namely Healthy Ireland. The use of individual-level data means that confounding factors, such as socioeconomic status, can be taken into account. This allowed the research team to generate more robust insights into the relationship between the environment and health and wellbeing.

Second, where survey data are not available, new data collection can provide insights into hitherto underresearched population groups. In collaboration with the National Biodiversity Data Centre (NBDC), we designed an online questionnaire to collect information on the demographic, health, social and attitudinal characteristics of newly recruited biodiversity data recorders in Ireland. To our knowledge, this is the first study to characterise a group of people engaged in environmental citizen science activities in terms of their health, wellbeing and physical activity. This allows us to establish a baseline for investigating effects of participation in citizen science activities on participants' health and wellbeing using a follow-up survey, which will be conducted in the next phase of this ongoing project (starting at the end of 2020).

Third, the research team analysed a range of firm-level datasets from Ireland's Central Statistics Office (CSO) (e.g. the Community Innovation Survey, the Census of Industrial Production and the Annual Services Enquiry) to provide novel evidence on (1) the effect of environmental regulations and other factors on the propensity of firms to introduce innovations with environmental benefits and the impact of these innovations on their export performance; and (2) determinants of firms' investments in environmental

protection and the impact of these investments on a broad range of firm performance outcomes, including output, employment, productivity, export intensity and energy intensity.

Finally, the use of behavioural science techniques, such as laboratory experiments and field trials, which involve the collection of new data, offers an opportunity to influence the design of policy interventions. In this phase of the programme, we focused on two areas of current policy concern: (1) the design of communications with householders in high radon risk areas (to encourage higher testing rates) and (2) the design of general communication strategies for the presentation of environmental information.

Much of the research carried out under the programme has been published in peer-reviewed journal articles. In these cases, we summarise the research in this report; additional material can be found in the full publications, which are referenced in each section. In other cases, research has only recently been completed and is awaiting publication, so this report contains a more detailed account of the work. For one topic, on the health and wellbeing impacts of engaging in biodiversity-recording activities, only the first phase of the research is summarised here (the second phase of that research involves further data collection, which is scheduled for the end of 2020/beginning of 2021). For the two behavioural science topics, the impact of the public health restrictions introduced as a result of the coronavirus disease 2019 (COVID-19) pandemic has meant that some data collection has been delayed; in these cases, the summary reflects progress up to June 2020. The remainder of the report discusses each of the topics in turn, before setting out some recommendations for policy.

2 Health and Wellbeing Effects of the Environment

Research by Peter Barlow, Philip Carthy, Seán Lyons and Anne Nolan.

2.1 Introduction

The natural and built environment is an important component of the "social determinants of health", i.e. the non-medical factors that determine our health and wellbeing throughout the life course. In phase I of the EPA/ESRI research programme, the research team pioneered the use of linked environment–health data at the individual level to examine the impact of radon risk on lung cancer (Dempsey *et al*., 2018a), the impact of urban green spaces on obesity (Dempsey *et al*., 2018b) and the impact of coastal blue spaces on mental health (Dempsey *et al*., 2018c). For these analyses, individual-level data on health and socioeconomic characteristics from TILDA were matched with spatially coded data on environmental exposures from a variety of sources, such as the EPA, the European Environment Agency (EEA) Urban Atlas and the Ordnance Survey Ireland (OSI). A key challenge in this area of research is establishing causality, as poor health, poor ambient environmental conditions and low socioeconomic status are often correlated. The use of individual-level data allows us to control for many confounding factors, such as socioeconomic status, and thus come up with more robust estimates of the impact of selected environmental exposures on health and wellbeing.

In phase II of the EPA/ESRI research programme, we extended the research carried out in phase I in a number of ways. First, we carried out further research on the impact of green spaces on obesity in order to try to understand the mechanisms underlying the relationship established in Dempsey *et al*. (2018b). Second, we examined the impact of additional environmental exposures, such as air pollution. Third, we used an additional source of survey data – Healthy Ireland – to broaden our focus to the full adult population. Sections 2.2–2.4 describe research findings for the three phase II studies that further developed our understanding of the links between the environment and health.

2.2 Walkable Green Spaces and Obesity

2.2.1 Background

Although exposure to urban green spaces has been associated with various physical health benefits, the evidence linking these spaces to lower body mass index (BMI) and obesity risk, particularly among older people, is mixed. In a study conducted for phase I of the EPA/ESRI research programme, we found evidence of a U-shaped relationship between urban green space availability and obesity (Dempsey *et al*., 2018b). One potential explanation for the counterintuitive results at the higher quintiles of green space exposure was that the study focused only on the amount of green space available in an individual's local area and not on the accessibility of that green space. The aim of this study was therefore to add to the literature on the association between urban green space and BMI by considering alternative measures of urban green space that incorporate measures of footpath availability.

2.2.2 Data and methods

Survey data from TILDA were used in this study. TILDA is a nationally representative survey of over 8000 individuals aged 50 and over, who were first surveyed in 2010. Participants are followed up every 2 years, with five waves of data collection completed to date. In addition to extensive information on household structure and socioeconomic characteristics, TILDA contains detailed information on numerous doctor-diagnosed health conditions (e.g. cardiovascular diseases, respiratory diseases and cancer), use of prescribed and over-the-counter medications, and validated indicators of wellbeing and mental health. The dataset also includes objective indicators of health collected as part of an extensive nurse-led health assessment (e.g. blood pressure, height and weight).

Respondents' exposure to urban green spaces at their residential addresses was assessed using street-side and area buffers that take account of the presence of footpaths. Data on green spaces and the footpath network were sourced from the OSI's Prime 2 model.

Generalised linear models were used to test the association between exposure to several measures of urban green space accessibility and BMI.

2.2.3 Results

Relative to the third quintile, living in an area with the lowest quintile of urban green space, as measured within a 1600 m footpath-accessible network buffer, was associated with a slightly higher BMI [marginal effect: 0.80; 95% confidence interval (CI): 0.16–1.44]. The results, however, were not robust to small changes in how green space was measured and no statistically significant association between urban green space and BMI was found under other variants of the regression model (see Figure 2.1).

2.2.4 Conclusions and policy implications

The results of this analysis show that the relationship between urban green spaces and BMI among older adults is highly sensitive to the characterisation of local green space. Our results suggest that there are some unobserved factors other than footpath availability that mediate the relationship between urban green space and weight status. Future work should, subject to data availability, consider factors that may impede the use of green spaces, such as inadequate lighting, restricted opening hours and the presence of anti-social behaviour.

The research underpinning this study has been published in a peer-reviewed academic journal (see Carthy *et al*., 2020a).

2.3 Air Pollution and Asthma

2.3.1 Background

Asthma affects over 300 million people worldwide. A growing body of research suggests that air pollution can contribute to the risk of developing asthma and the severity of the condition for those who suffer from it. However, the evidence of links between local air pollution and asthma is stronger for young people than

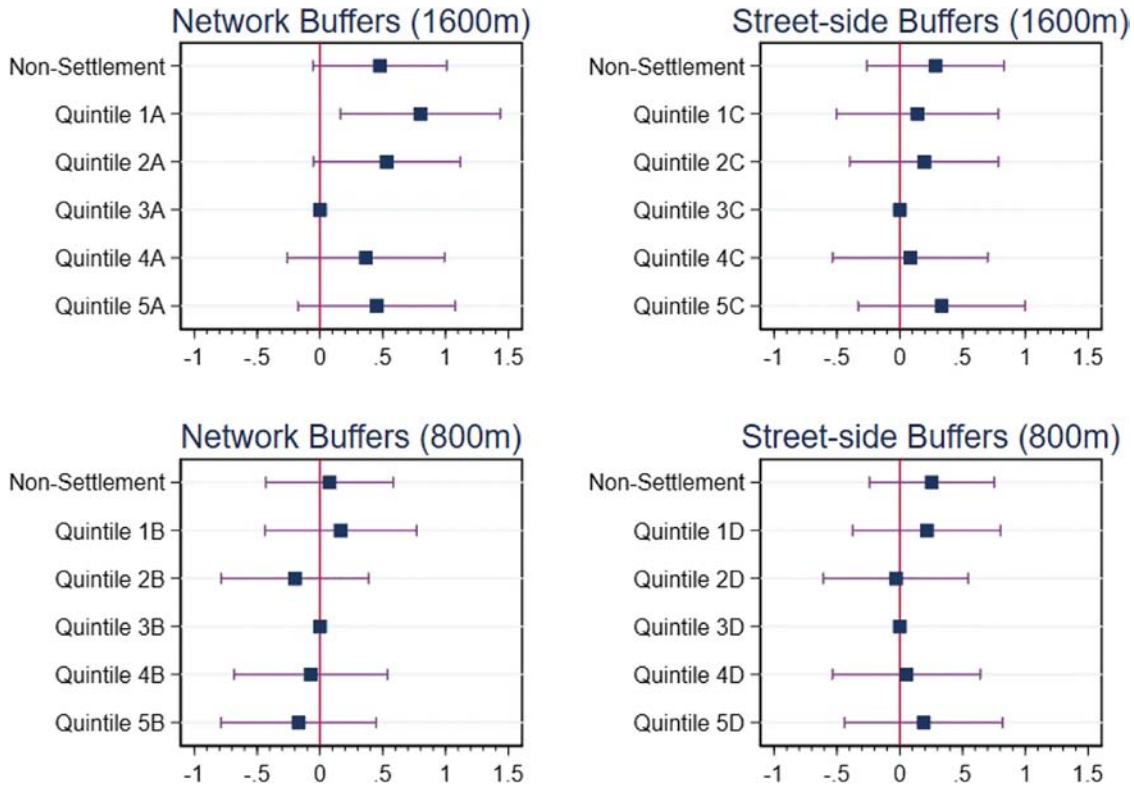

Figure 2.1. Marginal effects of footpath-accessible green space quintile on BMI, comparing street-side and network buffers at 800 m and 1600 m. Generalised linear model regression results. The values along the *x*-axis refer to marginal effects. Horizontal bars represent 95% CIs. Quintile 1 refers to the lowest quintile of footpath-accessible green space, whereas quintile 5 refers to the highest. Source: Figure 4 in Carthy *et al*. (2020a).

for older adults. In this study we examined whether or not asthma rates were higher among people aged over 50 years in Ireland who lived in areas with higher levels of local nitrogen dioxide (NO_2) air pollution. NO_2 is one of several pollutants emitted by motor vehicles and is often used as an indicator of transport-related air pollution more generally.

2.3.2 Data and methods

This study used survey data from TILDA (described previously in section 2.2.2). Information on participants' demographic characteristics, socioeconomic background and asthma status were linked to estimates of annual average NO_2 concentrations around their home addresses. Data on NO_2 exposure at TILDA participants' home addresses were based on a model developed for Ireland in previous research (Naughton *et al*., 2018). Figure 2.2 shows how the average NO_2 concentration varied across the TILDA sample; 95% of participants had levels of NO_2 below 13 parts per billion (ppb).

Respondents with asthma were identified in two ways: from a self-reported diagnosis or from the individual's use of medications normally prescribed for this condition. Regression models were then used to test whether or not individuals living in areas with higher NO_2 exposures were likely to have a higher risk of asthma than those living in areas with less air pollution. These models controlled for many other factors that might affect the likelihood of having asthma, including socioeconomic characteristics, age, sex, history of smoking and education level.

2.3.3 Results

Overall, 9% of the sample aged 50 and over reported an asthma diagnosis and 6.9% reported using relevant medications (e.g. inhalers). Living in an area with higher NO_2 concentrations was associated with an increased probability of asthma. For example, a 1 ppb increase in local NO_2 was associated with a 0.24 percentage point increase in the probability of reporting an asthma diagnosis, and the effect size was similar for the probability of using asthma medication (0.21 percentage points). To put these results in context, the average exposure to NO_2 in this sample was 4.8 ppb, with 95% of the sample exposed to NO_2 levels below 13 ppb.

2.3.4 Conclusions and policy implications

This study adds to the evidence that there is an association between NO_2 exposure and asthma

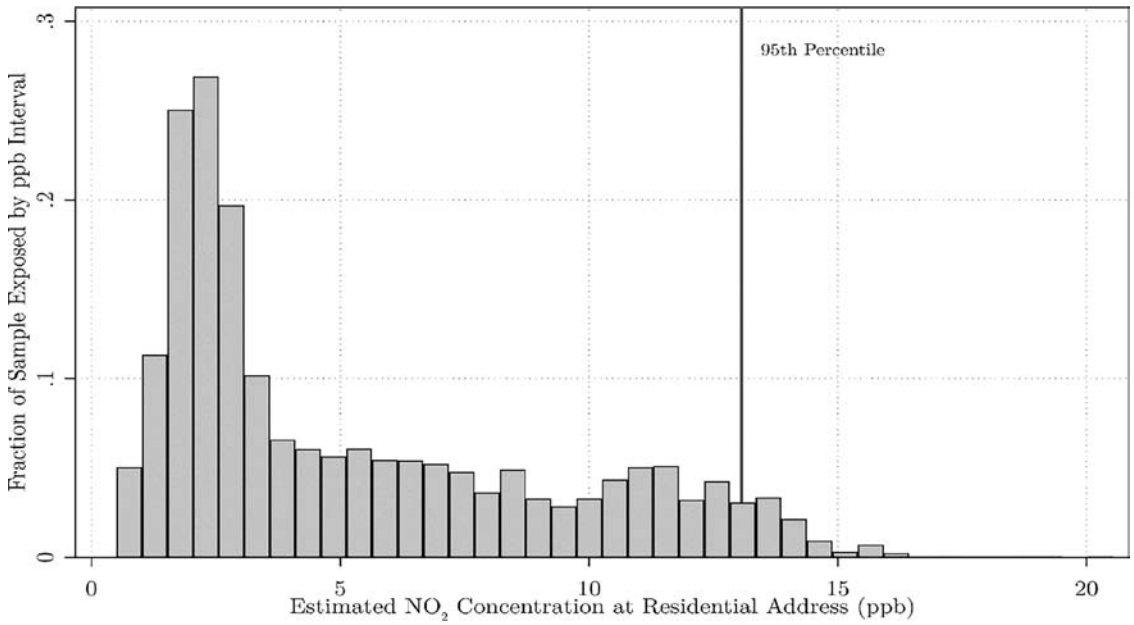

Figure 2.2. Frequency distribution of NO_2 exposure among TILDA participants. Source: Figure 3 in Carthy, P., O'Domhnaill, A., O'Mahony, M., Nolan, A., Moriarty, F., Broderick, B., Hennessy, M., Donnelly, A., Naughton, O. and Lyons, S. Local NO_2 concentrations and asthma among over-50s in Ireland: a microdata analysis. *International Journal of Epidemiology*, dyaa074, 2020, by permission of Oxford University Press.

among older adults, a group for which pollution exposures have received less research attention than for younger people. The study used a novel approach to identify asthma cases, taking account of both respondents' own reports of having asthma and separate evidence on their use of relevant medications. The results using the two methods were similar. Although levels of air pollution are relatively low in Ireland compared with many other countries and standard regulatory limits are rarely exceeded (EPA, 2019), we still found significant links between pollution and asthma rates. Finally, the individual-level data used in this study allowed us to control for many socioeconomic factors that might influence asthma rates and lead to misleading results if not taken into account.

The research underpinning this study has been published in a peer-reviewed academic journal (Carthy *et al*., 2020b).

2.4 Objective and Subjective Green Space

2.4.1 Background

Although exposure to urban green spaces has been associated with various physical health benefits, the mechanisms underlying the association between urban green space and health are less well understood. This study examines the relationship between perceptions of an open space problem in the local area and the amount of green space in that area, derived from objective measurements. The aim of the study is to provide further evidence for policymakers and practitioners on the features of green space that may encourage its use for physical activity, general recreation and social engagement, and thereby lead to better health.

Perceived and objective measures of green space provide an insight into the green space experienced by residents of an area. However, the perceptions may be influenced by wider factors such as area safety, area cleanliness and the availability of other services (e.g. access to public transport) in an area. By examining the impact of these factors, we can develop an understanding of the factors affecting the efficacy of green space in an area.

2.4.2 Data and methods

Healthy Ireland is an annual survey of the health and wellbeing of the population aged 15 and over. The first round of the survey was conducted in 2015, and five further rounds have been carried out to date. Different samples of approximately 7500 individuals are surveyed each year. A core set of demographic, socioeconomic and health and wellbeing characteristics are collected in face-to-face interviews each year, and each round also includes additional modules on selected topics of interest (e.g. parental health in round 5).

Wave 2 of Healthy Ireland (carried out in 2016) asked respondents "How much of a problem are each of the following in your neighbourhood?", with nine problems specified (such as "rubbish or litter lying around" and "vandalism and deliberate damage to property"). Respondents were asked to state whether each problem was "a big problem", "a bit of a problem" or "not a problem". The problem "lack of open public spaces" is our key dependent variable. Principal components analysis (PCA) on the remaining eight problems was employed to ascertain whether or not individuals perceived underlying problems with area-level safety, cleanliness and services provision in their local area.

Objective urban green space was measured using a geographic information system (GIS) and data on green space from the Urban Atlas produced by the EEA. Individuals were divided into five quintiles that represented the quantity of green space within 1.6 km (20-minute walking distance) of their residence. Those for whom no urban green space data are available (as they were not in a major urban area) were placed in a separate "rural" category.

We examined the association between objective green space and perceived open space problems using logistic regression. We also controlled for other perceptions of area-level problems (area-level safety, cleanliness, services) to examine whether or not these factors also partly explained perceptions of open space problems in an area. A full set of demographic and socioeconomic controls was also included.

2.4.3 Results

Overall, just under 10% of the sample reported that they had "a bit of a problem" or "a big problem" with the lack of open spaces. Figure 2.3 illustrates how

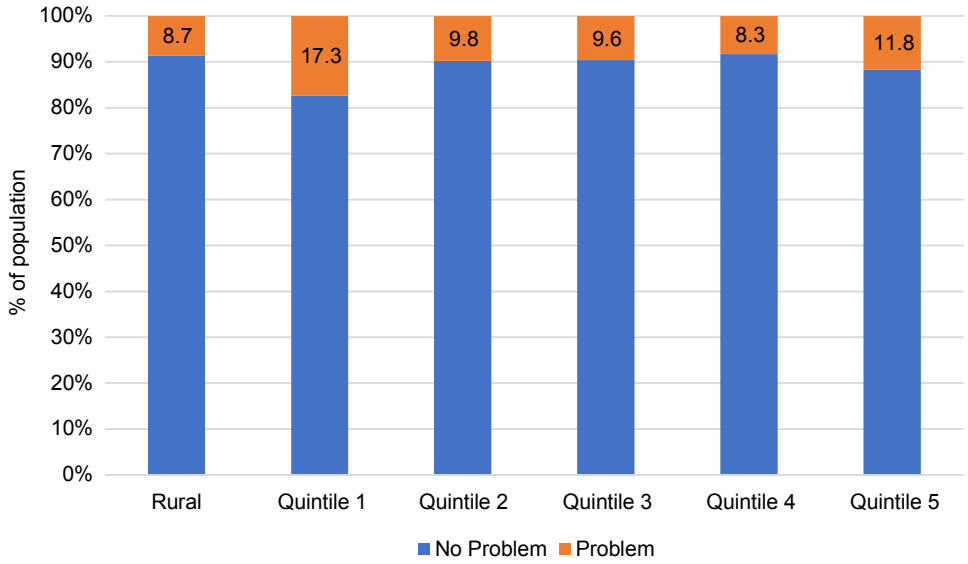

Figure 2.3. Proportion of those who perceive a problem with open space by green space quintile. Quintile 1 refers to those living in urban areas with the smallest amount of green space, whereas quintile 5 refers to those living in urban areas with the largest amount of green space.

the distribution of responses to this question varied depending on the level of urban green space in the local area.

In general, a higher proportion of those in areas with lower amounts of urban green space reported an open space problem (e.g. nearly 20% of those living in urban areas with the least amount of green space reported an open space problem). This relationship was consistent except in the case of the quintile with the highest objective urban green space; the proportion of respondents who perceived problems with open space was higher in this quintile than in some lower objective urban green space quintiles.

Table 2.1 presents the marginal effects from logistic models of the probability of perceiving a problem with "lack of open space". In addition to the measure of objective green space, this model included controls for other area-level problems (grouped into three categories relating to area-level safety, cleanliness and services), and it also controls for demographic and socioeconomic characteristics. Relative to those living in rural areas, those living in urban areas with the least amount of green space were 11.7 percentage points more likely to report that "lack of open space" was a problem. Those living in quintile 2 (with the next lowest level of urban green space) were also more likely to report an open space problem. Perceptions of

Table 2.1. Marginal effects from logistic regression of objective green space on perceived open space problem

Variable	Marginal effect
Rural area	Reference category
Green space quintile 1	0.117
	(0.030)[a]
Green space quintile 2	0.062
	(0.023)[a]
Green space quintile 3	0.024
	(0.017)
Green space quintile 4	0.000
	(0.015)
Green space quintile 5	0.034
	(0.019)
Area-level safety	0.037[a]
	(0.004)
Area-level cleanliness	–0.044[a]
	(0.005)
Area-level services	0.046[a]
	(0.004)
n	7347

Standard errors in parentheses. Quintile 1 has the least amount of urban green space and quintile 5 has the most amount of urban green space.

[a]Significant at 1% level.

area-level safety, cleanliness and services provision were also important; for example, those perceiving a problem with safety (e.g. crime, vandalism) in their local area were 3.7 percentage points more likely to report a problem with "lack of open space" in their local area.

2.4.4 Conclusions and policy implications

The analysis shows that, overall, less than 10% of Irish adults reported that they experienced a "lack of open space" in their local area. Relative to those living in rural areas, those with the least amounts of urban green space were more likely to report such a problem. Individuals who reported problems with service provision, safety and cleanliness in their local area were also more likely to perceive a problem with "lack of open space" in their local area, highlighting the importance of these factors for individuals' propensity to use their local green space. This suggests that, for any health benefits of green space to be realised, it must exist in the context of a safe, clean and well-serviced environment. Therefore, any investment in green space to improve health and wellbeing in an area should recognise the importance of the area's safety, cleanliness and service provision in facilitating the use of that green space.

A draft of this paper has been completed and is currently being finalised for submission to a peer-reviewed journal.

3 Characteristics of Biodiversity Data Recorders

Research by Ciarán Mac Domhnaill, Seán Lyons and Anne Nolan.

3.1 Introduction

Citizen science gives members of the public an opportunity to engage in scientific research and is an increasingly important tool for addressing conservation issues. In the first phase of this project, we contributed to the evidence base on who participates in environmental citizen science activities by examining the demographic, socioeconomic, attitudinal and health characteristics of biodiversity recorders in Ireland.

A better understanding of the demographic and attitudinal characteristics of environmental citizen scientists could help researchers to target recruitment campaigns and to design research activities that maximise the potential for involving citizen scientists. To our knowledge, this was the first study to characterise a group of people engaged in environmental citizen science activities in terms of their health, wellbeing and physical activity. This allows us to establish a baseline for investigating the effects of participation in citizen science activities on participants' health and wellbeing using a follow-up survey, which will be conducted in the next phase of this ongoing project (starting at the end of 2020).

3.2 Data and Methods

3.2.1 Biodiversity Recorder Survey

We collaborated with the NBDC to carry out an online survey of a group of people engaged in voluntary biodiversity observation and monitoring activities who had recently registered as biodiversity data recorders. We designed a new survey instrument, the Biodiversity Recorder Survey, employing questions drawn from existing large-scale socioeconomic surveys in Ireland. This allowed us to compare the demographic, socioeconomic, attitudinal and health characteristics of biodiversity recorders with the attributes of the wider population and to test for statistically significant differences between these groups.

The survey was sent by the NBDC to biodiversity recorders by email in February 2019. The survey was closed in April 2019, having received 438 valid responses with the sample size varying between questions. The survey was sent only to biodiversity recorders who had registered with the NBDC in the past year, allowing us to focus our study on a relatively homogeneous group of newly recruited citizen scientists.

3.2.2 Population data sources

Population data were sourced from the third wave of TILDA and the first wave of the Healthy Ireland survey, both of which have been described in detail previously in this report. We also utilised data on Irish participants from Special Eurobarometer 468 (European Commission, 2017), a public opinion survey on the attitudes of European citizens towards the environment, which involved face-to-face interviews with 1002 participants from Ireland.

3.2.3 Methodology

To compare the characteristics of our sample of biodiversity recorders with the population data sources, for each characteristic we tested the hypothesis that there was a statistically significant difference between the proportions of the two groups in variable categories. In the case of health, wellbeing and physical activity variables, however, any differences may have been at least partly the result of differences in demographic characteristics, for example biodiversity recorders tended to be more highly educated. Therefore, to help filter out such discrepancies explained by demographic differences, we employed a Blinder–Oaxaca decomposition. This statistical technique can determine the proportion of any gap in mean outcomes that can be explained by group differences in observed characteristics and the proportion that remains unexplained. In other words, this revealed any innate differences in outcomes between our sample of biodiversity recorders and the general population that would have existed even if our sample was endowed with the same demographic characteristics as the population.

3.3 Results of the Baseline Biodiversity Recorder Survey

As illustrated in Figures 3.1 and 3.2, we found biodiversity recorders to be more highly educated, less urban based, better off, more active in the labour force and more middle-aged than the general population. These findings were in broad agreement with previous research on the demographic characteristics of environmental citizen scientists.

As expected, given the nature of their voluntary conservation work, we found biodiversity recorders to be significantly more engaged in environmental protection. Recorders were more likely to regard environmental issues as having a direct impact on daily life and health and they were also more likely to perceive that they, as individuals, could play a role in protecting the environment in Ireland. We also asked respondents to choose up to four environmental issues that were most important to them, and responses among biodiversity recorders and the wider population are compared in Figure 3.3. Unsurprisingly, almost all biodiversity recorders identified the decline or extinction of species and ecosystems as one of the issues most important to them. Recorders also appeared more likely to select issues that could be regarded as having a more direct impact on biodiversity, such as the pollution of rivers and lakes, marine pollution and agricultural pollution. Conversely, issues that may affect biodiversity and natural ecosystems less directly, such as noise pollution, air pollution and shortages of drinking water, were less likely to be selected by biodiversity recorders.

We found mixed results in terms of health, wellbeing and physical activity, as shown in Figure 3.4. Accounting for observed differences in demographic characteristics between biodiversity recorders and the wider population using a Blinder–Oaxaca decomposition, we found that biodiversity recorders were 4 percentage points less likely to report either “good” or “very good” general health.

Meanwhile, as depicted in Figure 3.5, biodiversity recorders appeared to be more physically active than the general population. Even if our sample of biodiversity recorders was endowed with the same demographic characteristics as the population, they would still be 13 percentage points more likely to achieve the minimum recommended level of physical activity. Decomposition results also suggested that biodiversity recorders were 10 percentage points more likely to report having received a professional diagnosis of depression than the population, accounting for demographic differences.

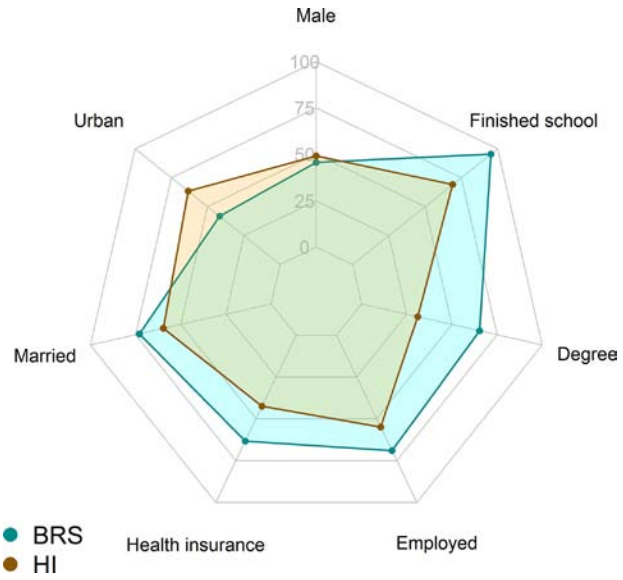

Figure 3.1. Demographic characteristics: comparison of biodiversity recorders and the adult population in Ireland using the Healthy Ireland survey. BRS, Biodiversity Recorder Survey; HI, Healthy Ireland.

3.4 Conclusions, Policy Implications and Further Research Plans

The study that forms the first phase of this project contributes to a growing evidence base that details the characteristics of people who engage in citizen science activities. Our findings suggest that younger people, people who live in urban areas, people who are unemployed and people with lower levels of education are all underrepresented in our sample of biodiversity recorders.

An objective of some environmental citizen science projects may be to foster enthusiasm for environmental protection. However, our results suggest that newly recruited biodiversity recorders are already extremely concerned about the decline or extinction of species and ecosystems. The scope for attitudinal change appears limited on account of the high rates of environmental concern reported during the early stages of participation.

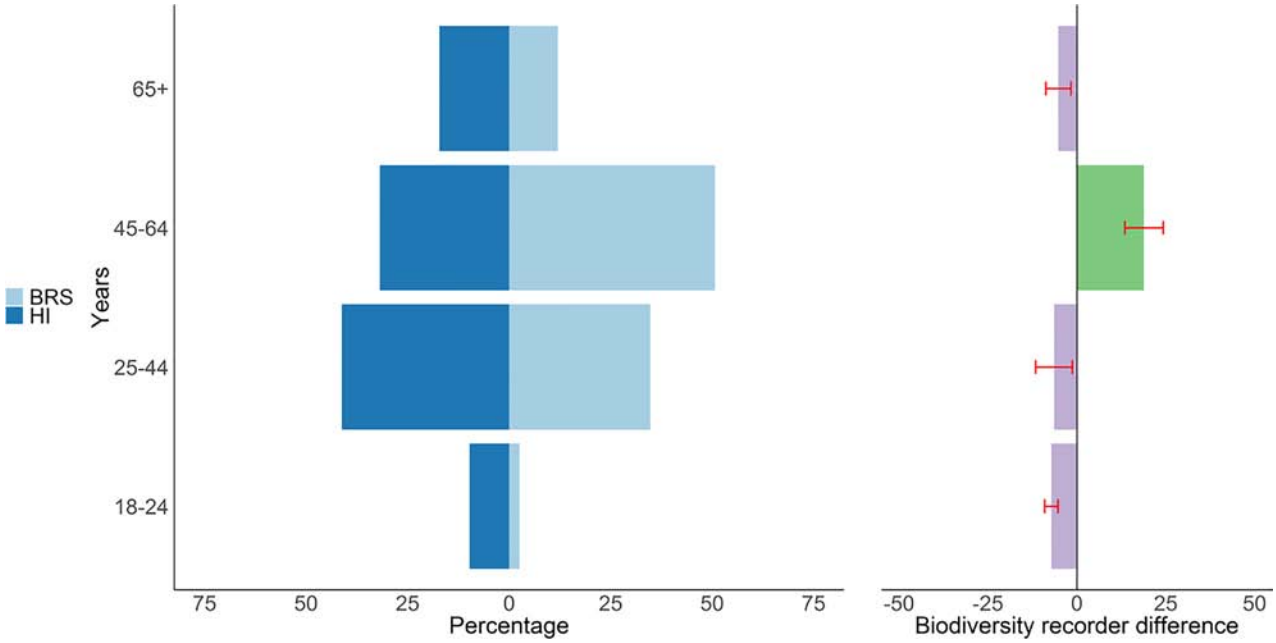

Figure 3.2. Age distribution: comparison of biodiversity recorders and the adult population in Ireland using the Healthy Ireland survey. BRS, Biodiversity Recorder Survey; HI, Healthy Ireland.

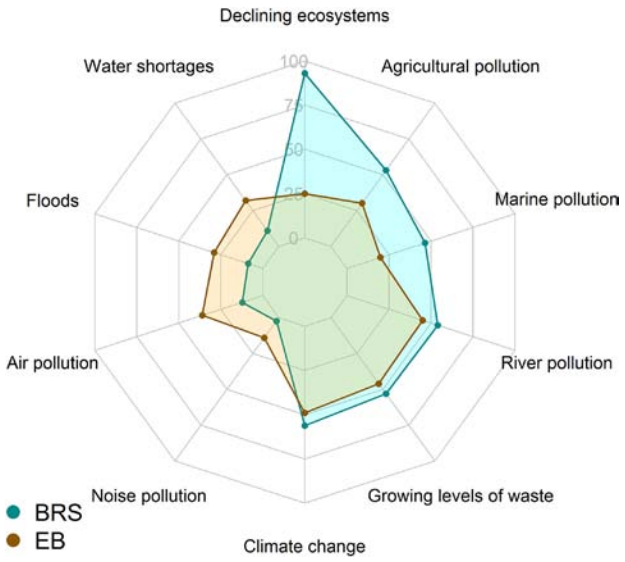

Figure 3.3. Environmental issues of concern: comparison of biodiversity recorders and the adult population in Ireland using Eurobarometer. BRS, Biodiversity Recorder Survey; EB, Eurobarometer.

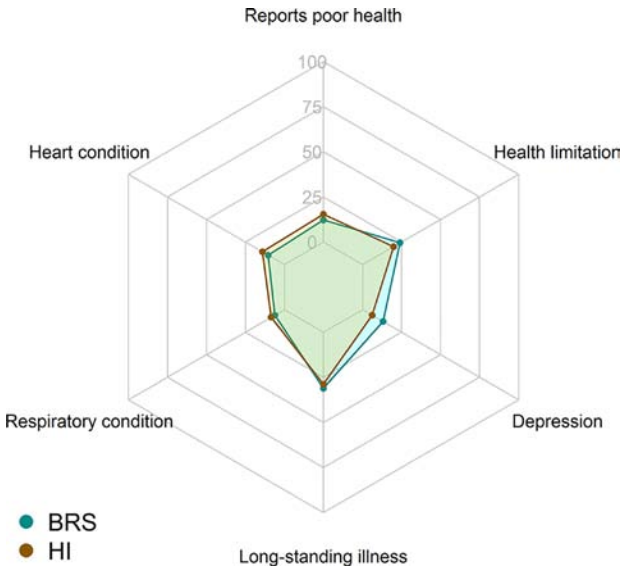

Figure 3.4. Health and wellbeing characteristics: comparison of biodiversity recorders and the adult population in Ireland using the Healthy Ireland survey. BRS, Biodiversity Recorder Survey; HI, Healthy Ireland.

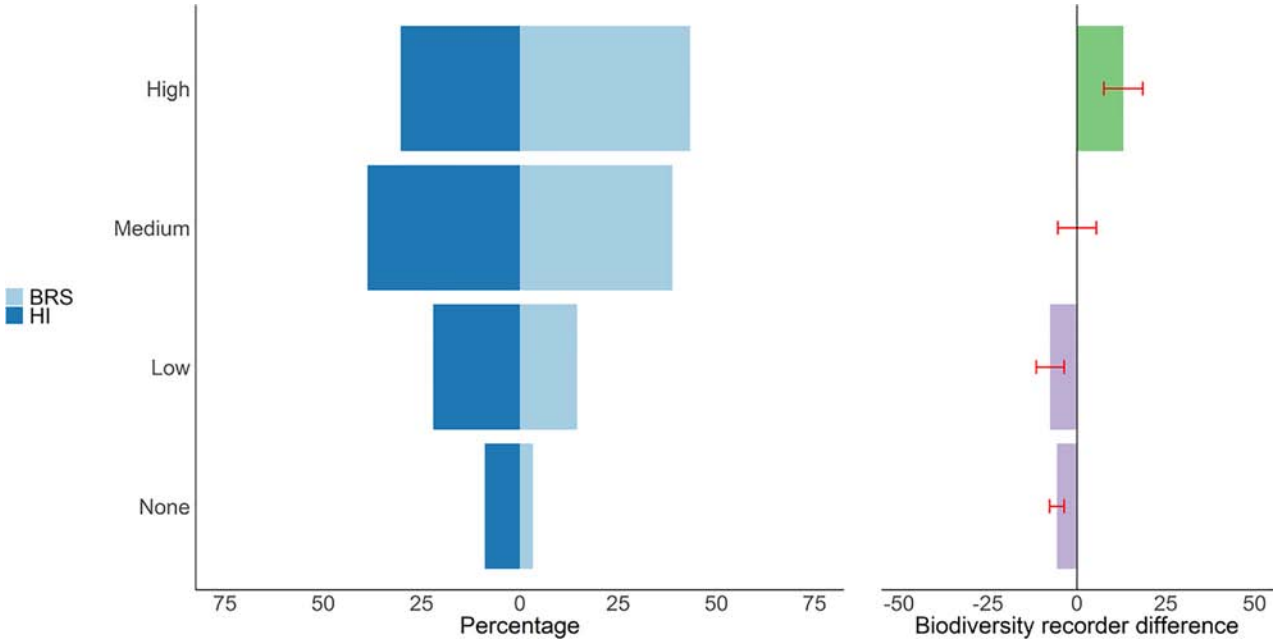

Figure 3.5. International Physical Activity Questionnaire score distribution: comparison of biodiversity recorders and the older adult population in Ireland using the Healthy Ireland survey. BRS, Biodiversity Recorder Survey; HI, Healthy Ireland.

This first phase study also establishes baseline health and wellbeing characteristics of biodiversity recorders in the early stages of their engagement with recording activities. In the next phase of this project, we hope to resurvey this sample of biodiversity recorders to examine whether or not participation in biodiversity recording activities is associated with different trajectories in terms of health and wellbeing, relative to control groups from population surveys. Further evidence on the benefits to participants of environmental citizen science activities could help support recruitment to such projects.

The research underpinning this study has been published in a peer-reviewed academic journal (Mac Domhnaill *et al*., 2020).

4 Designing and Testing Behaviourally Informed Regulatory Communications

Research by Shane Timmons, Deirdre Robertson and Pete Lunn.

4.1 Introduction

International research in applied behavioural science shows that regulatory compliance can be improved by behaviourally informing and testing aspects of regulatory delivery (e.g. Sunstein, 2011). The aim of this component of the programme was to employ techniques from behavioural science to design and test regulatory communications for use by the EPA. Following discussion with enforcement officers from the EPA between November 2018 and May 2019, it was agreed that the project would comprise two strands of research. The first would employ a randomised controlled trial (RCT) to increase the uptake of radon testing kits in high-risk areas. The second would use a controlled experimental approach to identify general framing strategies for pollution communications.

4.2 Testing for Radon in High-risk Areas

A trial design for the RCT to improve testing rates for radon in high-risk areas, as outlined in Table 4.1, was agreed in January 2020. Previous research indicates that simplifying the letter has the best chance of resulting in a positive effect, but there is also evidence to suggest that altering envelope designs and personalising communications can be effective. Hence, the logic is to test three manipulations (envelope design, simplification, personalisation). The design is "nested", with each experimental group building on the previous. This approach allows groups to be pooled to increase the sample size and permit a stronger statistical test of simplification (i.e. the control group and group 1 could be pooled and compared against the combined effect of groups 2 and 3), while still permitting tests of the other two behavioural levers.

In order to maximise the cost efficiency of the trial and the potential for positive tests, the focus will be on households with the highest risk (>20%) of radon exposure. Given that previous trials suggest a testing rate of 20% from delivered letters, the trial will initially target *c*.3500 houses. The aim of this sample size is to compare four forms of communications (including the standard letter), with 700 houses for each type of communication, allowing for a non-delivery rate of approximately 20% (as per previous trials).

Table 4.1. Experimental conditions for the RCT to improve radon testing rates

Group	Description
Control	Issued standard letter
	One-quarter of households will be reissued a letter used in previous trials in order to provide a baseline response rate for the experimental groups to be compared against
1	Redesigned envelope
	Previous research has found that simply altering the branding of envelopes can increase response rates (Tyers, 2017). One-quarter of households will be issued the same letter as the control group but in a redesigned envelope, in order to test whether or not simply opening the letter is a key barrier to remediation
2	Simplified letter + redesigned envelope
	In other RCTs run by the ESRI's Behavioural Research Unit, simplifying letters based on behavioural science led to significant increases in regulation compliance among previously non-compliant farmers. One-quarter of households will be issued a redesigned letter that uses similar behavioural principles to simplify the communication of relevant information. The letter will be issued in the same redesigned envelope as used in group 1
3	Simplified letter + area map + redesigned envelope
	Other research suggests that personalisation of regulatory communications can have a significant effect on response rates (Revenue Commissioners, 2019). In order to personalise radon risk information, the remaining households will receive the same letter and envelope as group 2, but with an image included of the risk map for the area their household is in

The implementation of the trial had been scheduled for late April 2020, although the COVID-19 pandemic has required that the trial be postponed. This delay has been used to inform the design of new radon risk area maps. ESRI has joined a steering group for the development of the new area maps, which will be tested as part of the trial in place of pre-existing maps. The current schedule is to implement the trial in late 2020, assuming that the trajectory of the COVID-19 pandemic and the Roadmap for Reopening Society and Business permits this.

4.3 Framing Strategies for Pollution Communication

4.3.1 Background

How information is presented or "framed" affects the extent to which people attend to that information and also the choices they make (Tversky and Kahneman, 1981). The use of moral language can be an especially effective way to frame information, as moral words tend to be highly salient and less susceptible to biases of inattention (Gantman and Van Bavel, 2015; Brady *et al*., 2020). However, people differ in the extent to which they hold particular moral concerns. Survey research shows that people who hold socially liberal views tend to highly value fairness and the prevention of harm, whereas people with more socially conservative views also moralise respect for loyalty and purity (Graham *et al*., 2009). An emerging body of research in behavioural science shows that aligning the presentation or framing of information with a recipient's concerns and values can be an especially effective way to improve engagement with that information (Feinberg and Willer, 2019). For example, in the USA, framing pro-environmental policies as concerns about the sanctity of nature rather than highlighting the importance of preventing harm to the planet increases support among conservatives (Feinberg and Willer, 2012).

Hence, the aim of this experiment was to test the moral frames that might be effective at improving engagement with pollution communications in Ireland. In particular, the aim was to determine whether or not regulatory actions under the EPA's remit are judged to be more important when framed using specific moral concerns. Additional aims included testing whether or not specific frames might be more effective among subgroups of individuals (e.g. among those with less concern for the environment), whether or not people respond differently to moral frames depending on if the regulations pertained to different types of pollution and whether a small company or a larger one was expected to adhere to the regulations.

4.3.2 Methods

Participants

Participants ($n = 1001$) were recruited by market research agencies to be nationally representative. In total, 800 people took part online and 201 completed the study on individual laptops "in the lab" at ESRI and were paid according to their recruitment platform norms. Responses from six participants were removed prior to analysis on account of issues with experimental software for the main task, leaving a total sample of 995 for analysis. Within this sample, 183 people were employed in managerial roles, and they might be expected to make decisions similar to that required in the main task. This subsample showed the same pattern of responses as the general sample and so are not distinguished in the main analyses reported below.

Materials, design and procedure

For the main experimental task, participants were asked to make decisions about a hypothetical company's environmental management plan. They were told the environmental management plan helps the company to follow the relevant environmental regulations but that, since each action on the plan costs time and money, decisions need to be made about which actions are the most important to try to achieve. Participants were informed that the company was small or medium-sized and that the kind of pollution at risk was either water or air pollution.

The plan consisted of the following four actions, which were selected to have broad application to the enforcement areas under the EPA's remit:

1. ensuring personnel are appropriately qualified and trained;
2. appropriate treatment of waste;
3. maintenance of equipment and systems;
4. monitoring and reporting of emissions.

For each participant, each action was randomly assigned a frame that corresponded to one of four moral values (harm, fairness, loyalty and purity). The frames were constructed using relevant words from the Moral Foundations Dictionary (Graham and Haidt, 2012). Example frames are presented in Table 4.2 and an example plan is presented in Figure 4.1.

Participants were then asked two questions about each plan. First, they were asked to *rank* the actions in order of importance, which forced a trade-off between each action–frame pairing. Second, they were asked to *rate* the overall importance of each action, taking into account that the company "has other priorities that require time and money, such as marketing, recruitment, and product development". This question allowed more variation in responses and hence could give a measure of more general opinions of the importance of adhering to environmental regulations. Participants rated each action on a scale from 1 ("Not particularly important overall") to 7 ("Extremely important overall"). They completed the task twice, with a different company and pollution type each time. The logic of this task is that, if there are no effects of moral frame, participants would judge only the

Table 4.2. Example moral frames and regulatory actions

Moral value	Frame	Broad action	Detailed action
Harm	Because we should *protect* the environment and prevent people from *suffering*…	Reporting	… we will ensure emissions levels are regularly monitored and reported to the regulator
Fairness	Because we should be *honest* and *fair* in following regulations…	Maintenance	… we will ensure relevant equipment and systems are maintained to appropriate standards
Purity	Because pollutants are *unnatural* and the environment should be *clean*…	Waste handling	… we will ensure all waste gasses are handled as hazardous waste
Loyalty	Because we are an *Irish* company and we should respect the *community*…	Personnel	… we will ensure all employees working on systems have proper qualifications

Italics denote target moral words. All words were selected from the Moral Foundations Dictionary, except for "Irish", and were used to evoke loyalty concerns.

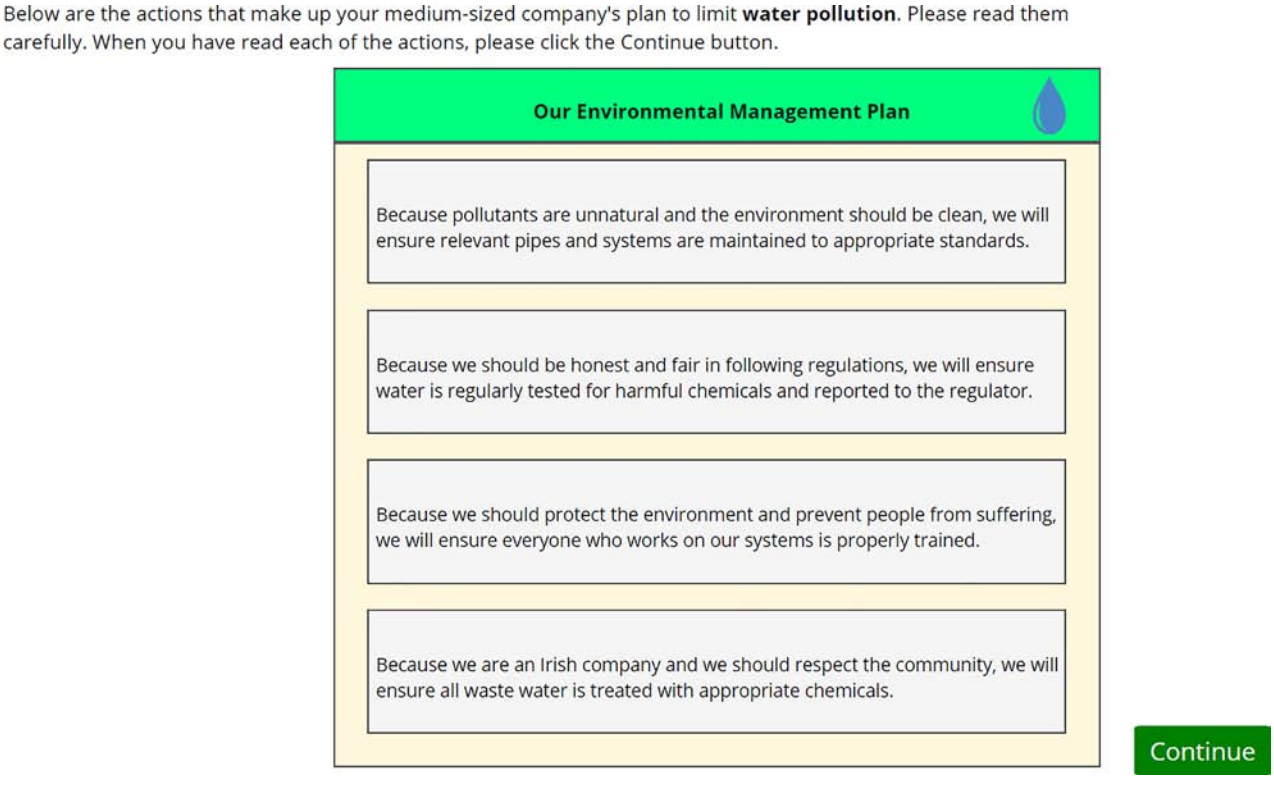

Figure 4.1. Example management plan presented as part of the experiment.

regulatory action and there would be no systematic differences depending on the frame used to rationale each action.

After ranking and rating the actions on both plans, participants completed a series of questionnaires, including the 5-item New Environmental Paradigm Scale (NEPS), which is a psychometrically validated measure of environmental concern (Dunlap, 2008).

4.3.3 Results

A chi-squared test showed a significant association between the frame and the rank participants assigned its action – χ^2 (9, $n = 7960$) = 479.01, $p < 0.001$, $V = 0.14$ (Figure 4.2). Residuals between observed and expected frequencies indicate that the effect was primarily driven by the high frequency of "harm" framed actions assigned a rank of 1 and the high frequency of "loyalty" framed actions assigned a rank of 4. Turning to the ratings of how important each action was overall, a one-way analysis of variance (ANOVA) testing the effect of frame showed a significant effect – F (3, $n = 7959$) = 17.05, $p < 0.001$. Post hoc Tukey honestly significant difference (HSD) tests showed that "harm" framed actions ($M = 5.97$, $SD = 1.15$) were rated as significantly more important than the other three frames. "Loyalty" framed actions ($M = 5.71$, $SD = 1.26$) were rated significantly less so. There was no difference between the "fairness" ($M = 5.88$, $SD = 1.15$) and "purity" ($M = 5.71$, $SD = 1.26$) frames.

These initial findings suggest that the frame used to rationalise each action had an effect on how important participants felt the regulations were.

To test whether or not participants' level of environmental concern was associated with the effects of the frame, we used ordered logistic regressions predicting (1) the rank assigned to each action and (2) its overall importance, with random effects at the participant level. In each model we controlled for the participant's age, gender, social class, educational attainment, the action that each frame was assigned to and the order in which it appeared.

We used a tertiary split on NEPS scores to divide participants into those who had low concern (below 18 on the NEPS, $n = 259$, 26%), moderate concern (18–23, $n = 437$, 44%) or high concern (above 23, $n = 300$, 30%). Model 1 in Table 4.3 tested for the interaction between environmental concern and the frame on the rank assigned to each action and showed a significant effect. Tests of coefficients, displayed in Table 4.4, revealed that although "harm" framed actions were ranked as most important at all levels of environmental concern, the effect of the frame strongly diminished the more concerned the participant was for the environment. For those low in concern, "harm" framed actions were ranked higher than the other frames and "loyalty" framed actions significantly lower. For those with moderate concern for the environment, there were fewer significant differences across the comparisons and effect sizes were weaker. Those with the highest level of concern differentiated the least between different frames and differences showed the smallest effect sizes. Further analyses suggested that the frame had a weaker effect for those highest in concern because they had stronger preferences for the actions they were tasked with ranking. In particular, they had a stronger preference to rank reporting emissions to the regulator as the most important action.

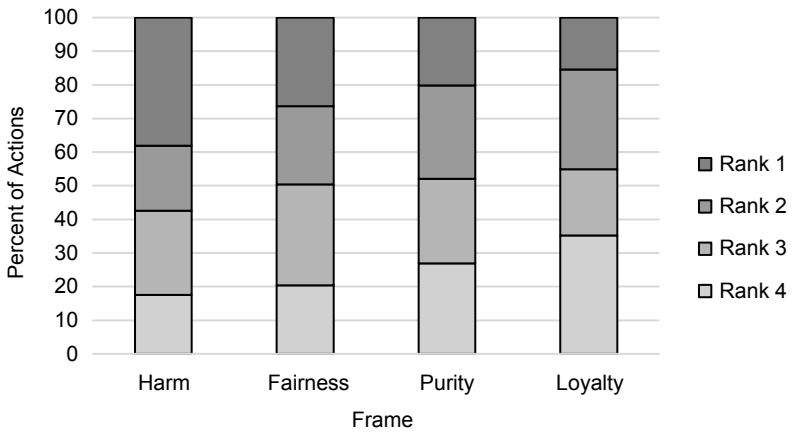

Figure 4.2. Ranks assigned to each moral frame.

Table 4.3. Mixed effects ordered logistic regressions of action rankings and ratings by frame and environmental concern

Variable	Model 1 (rankings)	Model 2a (ratings)	Model 2b (ratings)
Frame (Ref: Harm)			
Fairness	0.62[a] (0.11)	–0.29[b] (0.12)	–0.29[b] (0.12)
Purity	0.63[a] (0.11)	–0.15 (0.12)	–0.15 (0.12)
Loyalty	1.09[a] (0.11)	–0.62[a] (0.12)	–0.62[a] (0.12)
Environmental concern (Ref: Low)			
Moderate	0.18[c] (0.10)	0.54[a] (0.17)	0.54[a] (0.17)
High	0.14 (0.11)	0.79[a] (0.19)	0.79[a] (0.19)
Frame × environmental concern			
Fairness × moderate	–0.36[b] (0.14)	0.02 (0.15)	0.02 (0.15)
Fairness × high	–0.26[c] (0.15)	0.10 (0.17)	0.11 (0.17)
Purity × moderate	–0.03 (0.14)	–0.09 (0.16)	–0.09 (0.16)
Purity × high	–0.04 (0.15)	–0.30[c] (0.17)	–0.30[c] (0.17)
Loyalty × moderate	–0.30[b] (0.14)	0.03 (0.16)	0.03 (0.16)
Loyalty × high	–0.28[c] (0.16)	0.11 (0.17)	0.11 (0.17)
Larger company			0.21 (0.05)[a]
Water pollution			0.11 (0.05)[b]
Variable (Constant)	3.44 (0.07)	2.81 (0.18)	2.83 (0.18)
Observation	7960	7960	7960
n	995	995	995

Standard errors are in parentheses. Models include participant random effects and controls for participant gender, age, education and socioeconomic grade, action assigned to each frame and position on each plan.

[a]*p*<0.01.

[b]*p*<0.05.

[c]*p*<0.10.

Table 4.4. Chi-squared tests of coefficients for the interaction between frame and environmental concern in model 1

Level of concern	Frame	Fairness	Purity	Loyalty
Low	Fairness		0.01	18.09[a]
	Purity			17.28[a]
Moderate	Harm	6.52[b]	0.04	4.49[b]
	Fairness		5.82[b]	0.17
	Purity			3.88
High	Harm	2.92[c]	0.08	3.21[c]
	Fairness		2.13	2.39
	Purity			0.01

The comparison between "harm" framed actions and other frames for low concern participants are described in Table 4.3, showing all comparisons are significant at the 0.1% level.

[a]*p*<0.001.

[b]*p*<0.01.

[c]*p*<0.10.

Regarding how important each action was rated, in model 2a, having higher environmental concern was strongly associated with placing greater importance on following regulations, as would be expected. The model suggests that, for participants with low concern for the environment, "harm" framed actions were rated as more important than "fairness" and "loyalty" framed actions, but not "purity" framed ones. Both "fairness"

and “purity” framed actions were rated as more important than loyalty ones, with $\chi^2(1) = 7.64$, $p = 0.006$; and $\chi^2(1) = 15.04$, $p < 0.001$, respectively. There was little evidence for an interaction between concern and frame in this model, although the difference between “harm” framed and “purity” framed actions was marginally larger for those higher in environmental concern, with $\chi^2(1) = 3.02$, $p = 0.082$.

In model 2b we added company size and pollution type and found that participants judged following the regulations to be more important for larger companies and if the company’s activities posed a risk for water pollution. Testing for interactions between the frame and company size and the frame and pollution type showed no significant effects, implying that frames were similarly effective independent of these factors. Across all models that predict importance ratings, other sociodemographic variables emerged as significant standalone predictors. Women gave higher ratings overall than men, participants in older age categories gave higher ratings than those in younger age ones and those in lower social classes gave higher ratings than those in high social classes. Again, there were no interactions with the frames used on individual actions, suggesting a universal effect of frame.

4.3.4 Conclusion and policy implications

The results show that moral frames can alter the importance that people assign to different environmental regulations. Across all sociodemographic subgroups, participants judged regulations that highlighted the prevention of damage to the environment as more important than regulations framed in other moral concerns, independent of what those regulations entailed. The results echo other findings that people in Ireland are more willing to follow public health advice when communications emphasise the potential harms to others compared with when the advice is in the form of simplified instructions (Lunn *et al*., 2020). Of note in the present study is the counterintuitive finding that regulations that emphasised the importance of respecting the community and adhering to Irish values were *least* important. The same pattern was found among participants who were employed in roles that involved managerial decisions similar to those required by the experimental task and regardless of the size of the company and whether the potential pollution at risk was water or air pollution. Hence, the results imply that a broad communication strategy of highlighting the role that regulations have in protecting the environment and preventing related harms to people could be effective in multiple contexts.

The results also show that individuals with less concern for the environment showed a greater reliance on the frame when evaluating the regulations, whereas individuals with greater environmental concern tended to show greater preferences for specific actions and especially ones pertaining to monitoring emissions. This finding implies that such framing techniques may be particularly effective for communicating with individuals who may be more likely to breach regulations, assuming a relationship between lower environmental concern and a tendency to breach regulations. This finding may indicate that less environmental concern in Ireland reflects a lower likelihood to consider environmental harm, rather than active disregard. Of course, findings from a hypothetical experiment should be interpreted with some caution. These results are indicative of the kind of framing strategy that would likely be successful at improving receptivity to environmental regulations (e.g. underscoring the role of regulations in protecting the environment would probably be more effective than emphasising the importance of respecting the locality). Specific strategies would benefit from further iterative testing.

A draft of this paper has been completed and is currently being finalised for submission to a peer-reviewed journal.

5 Examining the Drivers and Consequences of Green Innovations and Green Investments

Research by Iulia Siedschlag, Stefano Meneto, Manuel Tong Koecklin and Weijie Yan.

5.1 Introduction

In this chapter, we summarise the results of four studies that were undertaken, examining data from a range of firm-level datasets provided by the CSO:[1]

- The effects of environmental regulations and other factors on the propensity of firms to introduce green innovations.
- Do green innovations improve firms' export performance?
- Factors that influence firms' decisions to spend on environmental protection.
- The effects of green investments on firm performance.

5.2 The Effects of Environmental Regulations and Other Factors on the Propensity of Firms to Introduce Green Innovations

5.2.1 Research and policy background

Economic theory and recent international evidence have established that green innovations (innovations with environmental benefits) are a key driver of sustainable long-term economic growth.[2] Given well-known negative externalities associated with environmental challenges and specific market failures, it is also increasingly accepted that government actions are needed to foster green innovations (OECD, 2011; United Nations Environment Programme, 2011). Understanding what drives the propensity of firms to introduce innovations with environmental benefits could improve the knowledge base of environmental policies aiming to incentivise firms to invest in green innovations.

This research examined the effects of environmental regulations and other factors on the propensity of firms to introduce green innovations. Using micro data from Ireland, in addition to environmental regulations, a range of factors were analysed suggested by the literature on innovation,[3] including innovation inputs, firm-specific characteristics, spillovers from other innovators (in the same industry and in the same region), co-operation for innovation activities and public funding. The analysis considered all innovations with environmental benefits as well as two specific innovation categories, namely innovations with environmental benefits within firms and innovations with environmental benefits for the final consumer. Furthermore, within these two broad innovation categories, green innovations by the type of environmental impact were analysed. The following environmental impacts were covered by the data: reduced material or water use; reduced energy use or carbon dioxide (CO_2) footprint; reduced air, water, noise or soil pollution; renewable energy sources; recycled waste, water or materials; facilitated recycling after use; and more durable products.

The novelty of this research is twofold. First, a comprehensive set of factors that influence the propensity of firms to introduce green innovations were analysed using a unified econometric framework. Second, in addition to average effects across all firms, the analysis took into account the potentially different innovation behaviour of firms and it was carried out separately for manufacturing and services firms and for indigenous and foreign-owned firms.

1 All results discussed in this chapter are based on the analysis of strictly controlled research microdata files provided by Ireland's CSO. The CSO does not take any responsibility for the views expressed or the outputs generated from this research.

2 For a recent review of international evidence see, for example, Smulders *et al*. (2015).

3 A review of this literature and evidence on factors influencing the innovation behaviour and innovation performance of firms in Ireland was provided by Siedschlag and Zhang (2015).

5.2.2 Data and empirical methodology

The main data source for this research was the Community Innovation Survey (CIS) 2014 for Ireland, undertaken by the CSO. The dataset contains information on the innovation activities of 3036 firms over the period 2012–2014. Additional data from the Census of Industrial Production (CIP) and the Annual Services Enquiry (ASI) from the CSO were used for the analysis of the effects of additional factors underlying the introduction of green innovations by firms, such as human capital, within-industry competition, export intensity, import intensity and energy intensity. The effects of factors that influenced firms' decisions to introduce innovations with environmental benefits were identified and quantified using probability models estimated with econometric methods.

5.2.3 Results

As shown in Figure 5.1, over the analysed period, on average, 40.1% of firms introduced innovations with environmental benefits. The rate of green innovation (the proportion of firms with green innovations) was the highest among large firms (67.1%). Small and medium-sized firms had lower rates of green innovation (46.1% and 34.6%, respectively). These innovation rates reflect the fact that large firms are more likely to innovate (Siedschlag and Zhang, 2015). Furthermore, large firms are more likely to invest in equipment for pollution control and in cleaner technologies (Siedschlag and Yan, 2020a).

Figure 5.2 shows that the rates of green innovation vary across sectors. The energy sector (electricity, gas, steam and air conditioning supply; and water supply, sewerage, waste management and remediation activities) had the highest green innovation rate (over 65%), followed by manufacturing (55%), mining and quarrying (41%), and transportation and storage (39%). Across the services sector, the highest green innovation rate was in transport and storage and the lowest in information and communication.

The key results of this research indicate that environmental regulations incentivise firms to introduce green innovations. On average, firms that had procedures in place to regularly identify and reduce the firm's environmental impacts were more likely to introduce green innovations. Firms that had such procedures in place in the period before 2012 had a higher probability, by 9 percentage points, of introducing green innovations than firms where such regulations were not in place. The effect of environmental regulations was larger – 25.6 percentage points in the case of environmental regulations implemented during the period 2012–2014. Analysing green innovations across different groups of firms, environmental regulations implemented before 2012 had the strongest effect on the propensity for services firms to introduce green innovations, whereas they did not matter significantly for the introduction of green innovations by manufacturing firms. Furthermore, such environmental regulations had a stronger effect for foreign-owned firms relative to indigenous firms. Environmental regulations that were

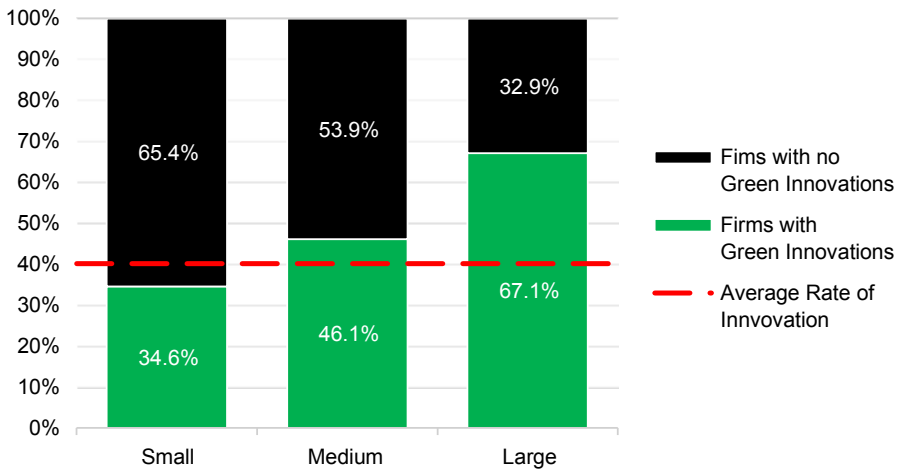

Figure 5.1. The proportion of firms with green innovations by firm size, 2012–2014. Source: authors' calculations based on data from CIS (CSO, Ireland).

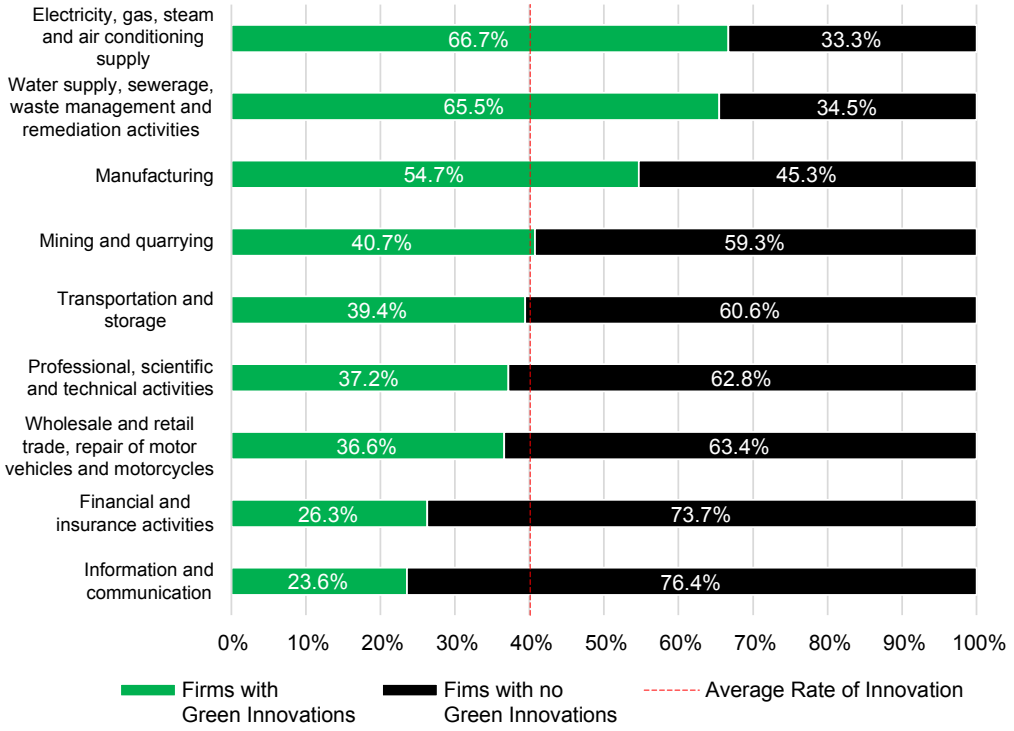

Figure 5.2. The proportion of firms with green innovations by sector, 2012–2014. Source: Authors' calculations based on data from CIS (CSO, Ireland).

implemented or which changed significantly during the 2012–2014 period had positive and significant effects on the introduction of green innovations in all groups of firms, with the strongest effect for manufacturing firms. When green innovations were analysed separately, taking into account the beneficiary of the innovations (the firm or the consumer), the effects appear to be larger in the case of more recent environmental regulations, with the largest effects in the case of green innovations with benefits within a firm in terms of reduced energy use or CO_2 footprint, recycled waste, water or materials. Regulations are also an important driver of green innovations with benefits for the end-user, the largest effects being found in the case of reduced energy use or CO_2 footprint.

Other major drivers of green innovations are found to be in-house research and development (R&D) activity and investment in tangible and intangible capital assets. Furthermore, the research results indicate that larger firms were more likely to introduce green innovations. This result holds for all firms as well as all sub-samples of firms analysed, with the exception of services firms. The propensity of services firms to introduce green innovations increased with the proportion of green innovators in the same industry. Such a spillover effect was not identified in the case of the other groups of firms. This result could reflect the fact that knowledge spillovers are more easily transmitted and absorbed in services firms (see, for example, Di Ubaldo *et al*., 2018). Relative to foreign-owned firms, indigenous firms were more likely to introduce green innovations with benefits for the end-user. This result holds across all firms, including for manufacturing and services firms.

Further results indicate that firms engaged in co-operation for innovation with firms in the same enterprise group and with competitors were more likely to introduce green innovations. The effect of co-operations with firms in the same enterprise group was driven by foreign-owned firms whereas the positive effect of co-operations with competitors was driven by services firms and indigenous firms. Co-operation with private clients increased the propensity of firms to introduce green innovations. Funding from local authorities was found to be positively associated with the propensity of firms to introduce green innovations. This effect appears to be driven by firms in services, although it does not appear to be statistically significant in the case of the other groups of firms. Public funding from the European Union was found to be positively and significantly associated with green innovations with benefits for the

end-user in the area of more durable products. This effect was identified for manufacturing firms and for indigenous firms. It was not statistically significant in the case of firms in services and foreign-owned firms.

5.2.4 Conclusions and policy implications

This research provides novel evidence on the effects of environmental regulations and other factors on the propensity of firms to introduce innovations with environmental benefits. The results indicate that environmental regulations incentivise firms to introduce green innovations. Other major drivers of green innovations are in-house R&D activity and investment in tangible and intangible assets, as well as firm size.

To the extent that green innovations lead to an improved environmental quality, this evidence suggests that there could be a need for targeted policy measures to enable and foster green innovations by small and medium-sized firms. These firms are more likely than large firms to face market failures and financing constraints when they consider their engagement in R&D activity and green innovation.

This research has been published as an ESRI Working Paper (see Siedschlag *et al*., 2019).

5.3 Do Green Innovations Improve Firms' Export Performance?

5.3.1 Research and policy background

Understanding the effects of green innovations on the international competitiveness of firms is important for the design of policy measures that are aimed at a more sustainable and energy-efficient production and a wider acceptability of such measures. Although there is strong evidence that environmental regulations induce innovation activity in green technologies, less is known on whether or not the benefits from these innovations lead to an increase in firms' competitiveness (Dechezleprêtre and Sato, 2017). Recent evidence finds that regulation-induced innovation in clean technologies increases the innovation activity and competitiveness of unregulated companies through knowledge spillovers (Dechezleprêtre *et al*., 2014). Additional relevant evidence indicates that environmental regulations improve productivity in sectors exposed to international competition (Lanoie *et al*., 2008).

Against this background, using firm-level data from Ireland, this study contributes to filling the evidence gap on the relationship between policy-induced green innovations and firms' competitiveness measured as export performance.

5.3.2 Data and empirical methodology

The data used for this analysis comes from CIS 2014 for Ireland, which provides information on innovation activities of enterprises with 10 and more employees from industry and market-based services in Ireland over the period 2012–2014. It is a stratified random sample, stratified by firm size and two-digit NACE (the statistical classification of economic activities in the European Community) industries at the national level. The dataset we analyse contains anonymised information on 3036 firms.

Given that the export sales are observed for exporters only, the firms' export performance is modelled in two steps. In the first stage (export selection equation), export participation is estimated as a function of innovations with environmental benefits and other factors that have been found to influence the propensity of firms to export, including firm size, investment in R&D, productivity, previous exporting activity and ownership, as well as unobserved industry characteristics. In the second stage (export intensity equation), we estimate export intensity (export sales as a proportion of total sales) conditional on export participation, as a function of innovations with environmental benefits and other factors, including the intensity of R&D expenditures, productivity, previous exporting experience and unobserved industry characteristics.

5.3.3 Results

On average, 40% of all enterprises reported green innovations over the period 2012–2014. Taking into account the beneficiary of the green innovations, on average, 34% of enterprises had green innovations with benefits for the enterprise, whereas 28% of enterprises had introduced green innovations with benefits for the consumer. Analysing different green innovations outcomes, the innovation rate was the

highest for organisational innovation (27%), followed by process innovation (24%), marketing innovation (23%) and product innovation (22%).

Figure 5.3 shows the proportion of exporting and non-exporting firms among green innovators by sector over the analysed period. The three top sectors with the highest export participation rates were manufacturing; information and communication; and professional, scientific and technical activities. The three lowest export participation rates were in transportation and storage; financial and insurance activities; and water supply, sewerage, waste management and remediation activities.

The results from the econometric analysis indicate that green innovations with benefits for the consumer and product innovations with environmental benefits were positively associated with firms' export participation. Firms with innovations with environmental benefits for the consumer were more likely to export, by 7.2 percentage points, than the rest of the firms. Furthermore, firms with product innovations with environmental benefits were more likely to export, by 10.2 percentage points, compared with the rest of firms. Finally, the research results indicate that, conditional on export participation, green innovations did not appear to impact on how much firms exported over and above other factors, such as productivity, R&D intensity and foreign ownership.

5.3.4 Conclusions and policy implications

This study provides novel evidence on the relationship between green innovations introduced by firms and their international competitiveness. The results of this research indicate that green innovations with benefits for the consumer and product innovations with environmental benefits are positively associated with firms' export participation. The propensity to export is higher, by 7.2 percentage points, in the case of firms with innovations with environmental benefits for the consumer and by 10.2 percentage points in the case of firms with product innovations with environmental benefits. Furthermore, our results indicate that, conditional on export participation, green innovations do not appear to impact on how much firms export.

Taken together, our results suggest that environmental policy-induced innovations could be beneficial for environmental quality as well as the international competitiveness of firms measured as export participation.

This research has been published as an ESRI working paper (see Meneto and Siedschlag, 2020).

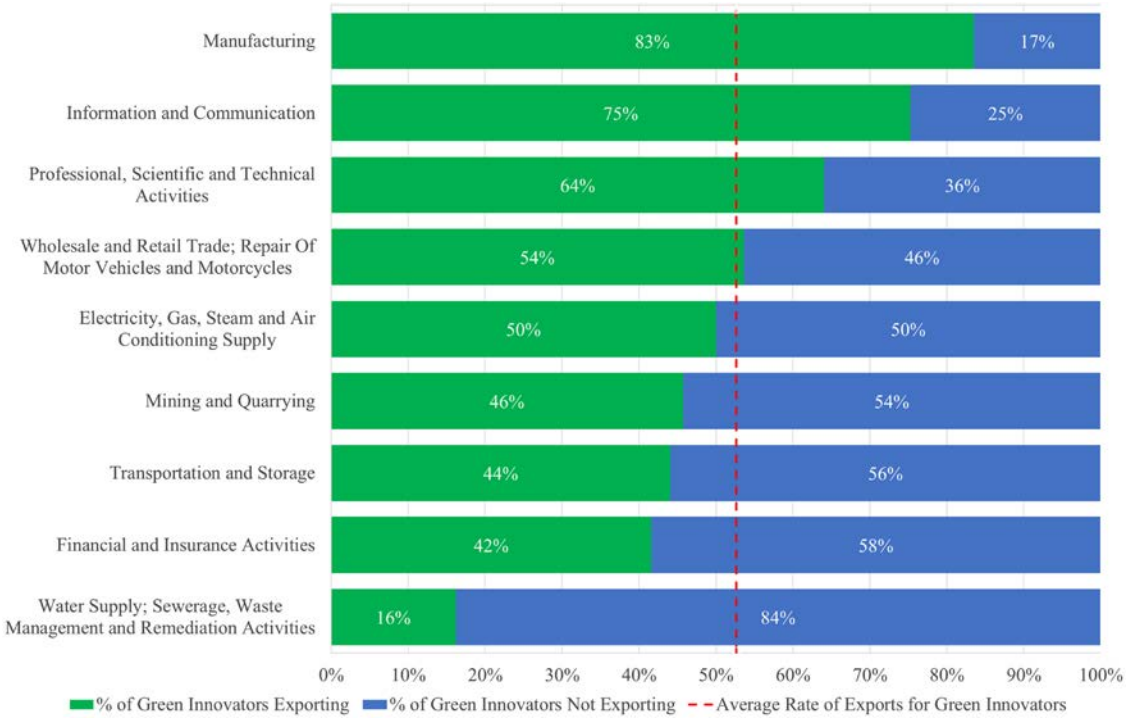

Figure 5.3. Export participation of green innovators by sector. Source: authors' elaboration based on data from CIS 2014 (CSO, Ireland).

5.4 Factors That Influence Firms' Decisions to Spend on Environmental Protection

5.4.1 Research and policy background

This research examined factors underlying firms' capital and current expenditures on environmental protection in the industry sector in Ireland. Specifically, the analysis quantified the importance of firm characteristics, environmental regulations, competition and spillover effects from firms in the same industry or the same region. Understanding what drives firms' decisions to spend on environmental protection is important for the design of policy measures aimed at improving environmental quality and resource efficiency.

5.4.2 Data and empirical methodology

The research used data from the CIP survey available for the period 2008–2016 from the CSO. The survey covers enterprises in the industry sector with three and more persons engaged.

5.4.3 Results

The results indicate that larger firms, importers and firms that were part of an enterprise group were more likely to invest in equipment for pollution control and equipment linked to cleaner technologies. Foreign-owned firms were found to be less likely than local firms to invest in environmental protection, particularly foreign affiliates of companies with headquarters based in the USA or in the eurozone. This result might reflect the fact that these foreign affiliates already had adequate equipment for air pollution control and cleaner technologies and that there was no need for further investment. The energy intensity of firms' production was positively linked to their propensity to invest in equipment for pollution control and to spend on environmental protection.

Within-industry competition measured as market share and market concentration was found to be an important driver of firms' investment in equipment linked to cleaner technologies. Although environmental regulations increased the likelihood of firms' current expenditures on environmental protection, they did not appear to have a significant impact on firms' investment in environmental protection. This insignificant impact might reflect aggregation bias given that, as a result of confidentiality restrictions, a measure of industry, rather than firm-level exposure to environmental regulations, was used in the analysis.

Finally, the results uncover significant positive spillover effects from firms with capital and current expenditures on environmental protection in the same industry or the same region on firms' propensity to invest and spend on environmental protection.

5.4.4 Conclusions and policy implications

To the extent that incentivising more firms to invest in environmental protection could contribute to improved environmental quality, the results of this study suggest that there could be a need for targeted policy measures to enable small and medium-sized firms in particular to invest in environmental protection. The findings also suggest that facilitating learning from firms with green investments within the same industry and within the same region could foster firms' investments in environmental protection.

This research has been published as an ESRI Working Paper (see Siedschlag and Yan, 2020a).

5.5 The Effects of Green Investments on Firm Performance

5.5.1 Research and policy background

Environmental policies affect production processes, resource allocation, capital investment, labour intensity and innovation incentives. Understanding how environmental policy has an impact on firm performance is important for the design of policies aimed at improving environmental quality and the wider acceptability of such policies.

This research examined the impact of firms' green investments on a range of performance outcomes, including the growth of output, employment, productivity, export intensity and energy intensity. The analysis used firm-level data from Ireland's industry sector over the period 2008–2016. In addition to average effects across all firms, heterogeneous effects for different groups of firms and industries were identified and quantified.

5.5.2 Data and empirical methodology

The data used for this analysis come from the CIP survey carried out by the CSO. The survey covers industrial enterprises with three and more persons engaged. The CIP survey data have a good representation of Ireland's industry sector, accounting for 97% of the total industrial turnover, and enterprises that responded to the survey represented 92% of total employment (CSO, 2018). The analysis in this study focused on the manufacturing and utilities sectors.

Green investments are identified as the sum of investment (capital expenditures) in plant and equipment for the purposes of pollution control and investment in plant and equipment linked to cleaner technologies. The investment figures are obtained from reported information on changes in capital stocks.

To assess the impact of green investments on firms' performance, a difference-in-difference propensity score matching methodology was employed following Blundell and Costa Dias (2000). The basic idea is that if two firms with similar characteristics exist, one of which reports green investments ("treated" firm) and the other one does not ("control" firm), the difference in their performance change before and after green investments is probably the result of green investments ("treatment"). This empirical approach allows us to compare the performance of firms that are similar before "treatment" (green investment) and to eliminate the impact of temporary unobserved firm-specific shocks to firm performance that might bias our results.

5.5.3 Results

Figure 5.4 presents the proportion of firms with investment in environmental protection by industry, where an industry is defined at the two-digit NACE Rev. 2 classification.[4] On average, only 3.9% of firms invested in equipment for pollution control in a year and only 3.7% of firms invested in equipment linked to cleaner technologies. As shown in Figure 5.4, in comparison with manufacturing, the energy sector has a much higher rate of investment in equipment linked to cleaner technologies, around 20% in the analysed dataset. This result probably reflects the strong regulations on emissions in place in this sector.

Figure 5.5 shows that the rates of green investments were similar across different regions in Ireland. Among all firms, the rate of investment in equipment for pollution control or for investment in equipment linked to cleaner technology was lower than 5.5%. In comparison with firms in other regions, firms located in the midlands region had a slightly higher investment rate in the case of investment in equipment linked to cleaner technologies, although they invested less in equipment for pollution control. Firms in the south-east had high investment rates in the case of both green investments. In contrast, firms in the south-west and west had low investment rates in both green investments.

The results of the econometric analysis indicate that, in the medium term, green investments had positive and statistically significant effects on firms' performance. Figure 5.6 shows the average effects across all firms over 3 and 5 years after the investment took place. On average, over a period of 5 years, green investments increased the growth of output of green investors by 21.7%, whereas their employment growth was higher by 3.4% and productivity growth was higher by 13.2%. Green investments have led to a reduction of energy intensity (fuel consumption per employee) by 5.7%. No statistically significant effects of green investments

4 The NACE Rev. 2 classification codes used in Figure 5.4 are as follows: 10 – Manufacture of food products; 11 – Manufacture of beverages; 12 – Manufacture of tobacco products; 13 – Manufacture of textiles; 14 – Manufacture of wearing apparel; 15 – Manufacture of leather and related products; 16 – Manufacture of wood and products of wood and cork, except furniture, and manufacture of articles of straw and plaiting materials; 17 – Manufacture of paper and paper products; 18 – Printing of reproduction of recorded media; 19 – Manufacture of coke and refined petroleum products; 20 – Manufacture of chemicals and chemical products; 21 – Manufacture of basic pharmaceutical products and pharmaceutical preparations; 22 – Manufacture of rubber and plastic products; 23 – Manufacture of other non-metallic mineral products; 24 – Manufacture of basic metals; 25 – Manufacture of fabricated metal products, except machinery and equipment; 26 – Manufacture of computer, electronic and optical products; 27 – Manufacture of electrical equipment; 28 – Manufacture of machinery and equipment not elsewhere classified; 29 – Manufacture of motor vehicles, trailers and semi-trailers; 30 – Manufacture of other transport equipment; 31 – Manufacture of furniture; 32 – Other manufacturing; 33 – Repair and installation of machinery and equipment; 35 – Electricity, gas, steam and air conditioning supply; 37 – Sewerage; 38 – Collection, treatment and disposal activities and materials recovery; and 39 – Remediation activities and other waste management services.

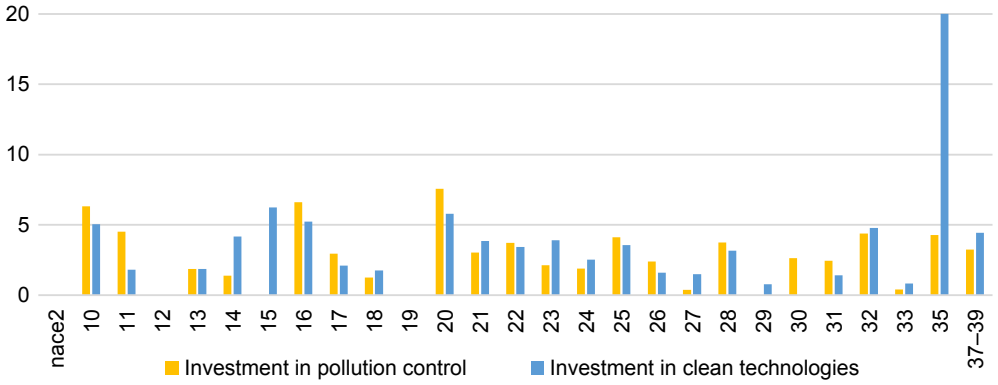

Figure 5.4. Green investment rates by industry, 2008–2016. Source: authors' estimates based on data from CIP (CSO, Ireland).

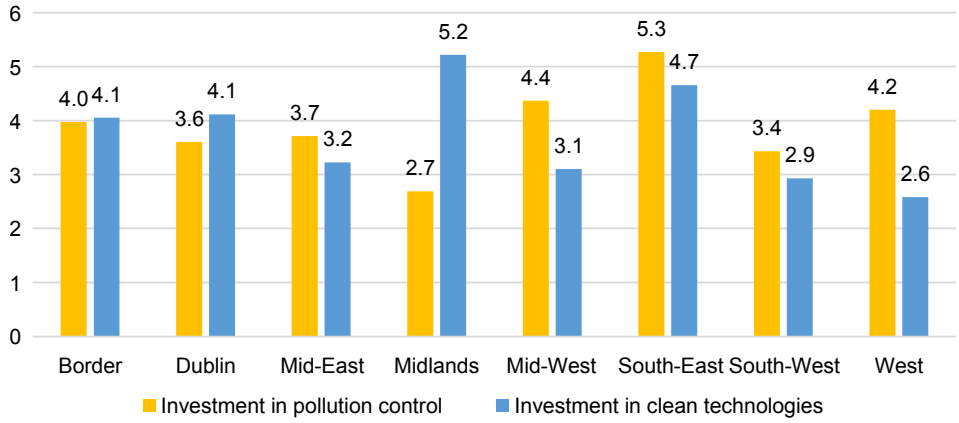

Figure 5.5. Green investment rates by region, for the period 2008–2016. Source: authors' calculations based on data from CIS (CSO, Ireland), 2008–2016.

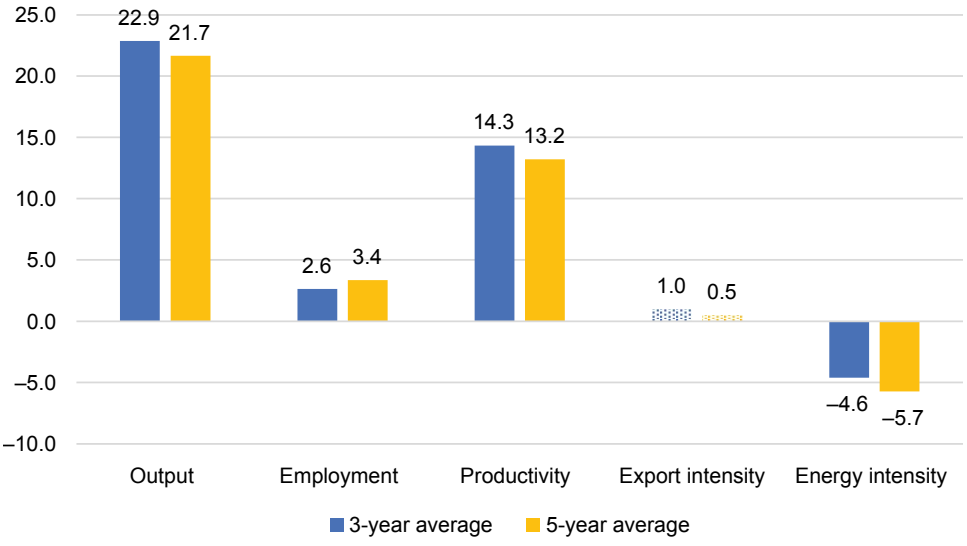

Figure 5.6. The effects of green investments on firm performance, all firms, 3- and 5-year average effects. A solid fill indicates statistical significance at the 90% level. Source: authors' estimates using data from CIP (CSO, Ireland), 2008–2016.

were found on the export intensity (export sales over total sales) of green investors.

Taking into account firm heterogeneity, the effects were found to be stronger for firms that were larger, foreign owned, more productive and in low-tech industries. The output and productivity performance of firms with green investments in the food industry was better than the average performance of all firms. Heterogeneous effects indicate that not all firms benefitted equally from green investments. These results are summarised in Table 5.1.

5.5.5 Conclusions and Policy Implications

Taken together, the results of this research suggest that environmental quality and firm performance go together. However, the evidence indicates that not all firms benefit equally from green investments. This result suggests that in the medium term not all firms have the capacity to generate substantial benefits from green investments to outweigh the associated costs. Such benefits could be larger for all firms in the long term. Longer time series, when available, would allow for an examination of this possible outcome.

This research has been published as an ESRI Working Paper (see Siedschlag and Yan, 2020b).

Table 5.1. Differential effects of green investments on firm performance by firm group, 5-year average

Firm Group	Output (%)	Employment (%)	Productivity (%)	Export intensity (%)	Energy intensity (%)
Medium-sized and large firms	**17.1**	**4.2**	**9.6**	–0.7	**–10.8**
Small firms	15.0	–4.3	15.5	4.5	0.0
Irish owned	4.6	–1.0	6.1	–0.1	–2.7
Foreign owned	**28.4**	**6.0**	**17.0**	1.2	**–8.7**
High productivity	**27.7**	**3.2**	**18.7**	–1.0	**–6.1**
Low productivity	4.8	3.0	0.7	4.8	–6.8
High energy intensity	**28.6**	**2.3**	**19.2**	1.2	–4.5
Low energy intensity	–10.1	–0.1	–7.2	0.2	–1.4
Medium- and high-tech industry	7.2	2.1	5.2	0.8	–0.4
Low-tech industry	**27.7**	**4.3**	**16.8**	1.7	**–8.2**
Food industry	**35.5**	**4.6**	**21.7**	3.7	**–12.4**

Figures in bold are statistically significant at 90% level.

Source: authors' estimates using data from CIP for the period 2008–2016 (CSO, Ireland).

6 Land Use and Spatial Planning Issues

Research by Achim Ahrens, Tom Gillespie, Ronan Lyons and Seán Lyons.

6.1 Introduction

The final two studies in phase II of the programme extended research carried out in phase I on land use and spatial planning issues. The first, on the relationship between urban rents and commuting patterns, followed on from previous research that summarised trends in land use changes and urbanisation in Ireland since 1990 and showed that a significant proportion of urban land use had been extended to remote areas, thereby exacerbating sprawl (Ahrens and Lyons, 2019). The second, on the relationship between green space and property values, extended research carried out in phase I that examined the value of coastal amenities using similar methods (Gillespie *et al*., 2019).

6.2 Urban Rents and Commuting

6.2.1 Background

City workers often face a trade-off between paying high housing costs to live close to work and making long commutes from areas with lower costs of accommodation. Researchers studying the development of cities have suggested that when rents increase in an urban centre, this leads to longer average commuting times. This paper measured the association between urban rents and commuting times in Ireland using data from the period 2011–2016, during which rents rose substantially.

6.2.2 Data and methods

The study used data from the CSO Place of Work, School or College (POWSCAR) datasets for 2011 and 2016, which are based on data from Ireland's censuses. The census records the location of residence and place of work for all workers in Ireland and these data were used to measure the numbers of commuters between each pair of electoral divisions (EDs) in the country (there are 3409 of these areas). Mobile workers, commuters who start and finish within the same ED and those who work at home were excluded. Figure 6.1 illustrates the flow of origin–destination commuting flows in 2016.

Information on residential rents in 5-year periods up to each census was obtained from Ireland's Residential Tenancies Board. The law requires that all tenancy agreements in Ireland are registered with this body.

Regression models were used to explore how the probability of commuting between origin and destination pairs of EDs was related to rent, controlling for the number of residents, the number of jobs, other demographic factors and socioeconomic variables describing the areas.

6.2.3 Results

As expected, average residential rents tended to be highest in areas with greater employment density.

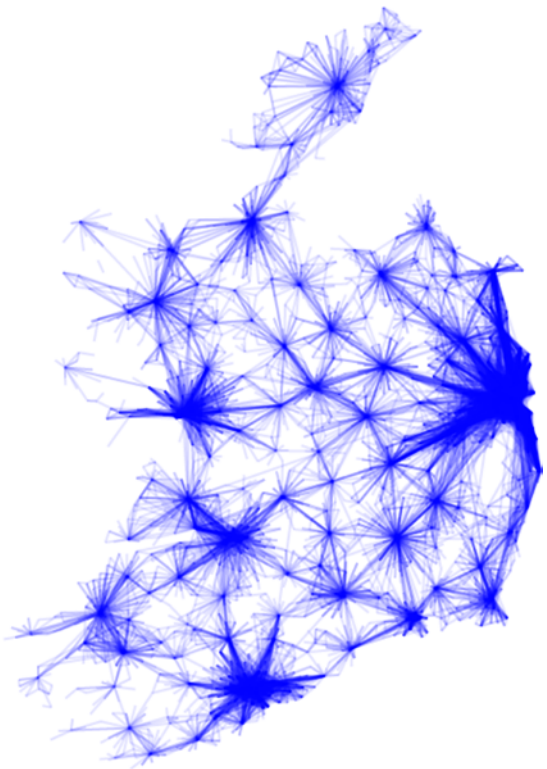

Figure 6.1. Map of bilateral commuting flows in Ireland in 2016. Source: Figure 1 in Ahrens and Lyons (2020).

The analysis shows a statistically significant positive relationship between the difference in rent between pairs of areas and the commuting time between them. A 10% rise in rent in Ireland's employment centres was associated with an up to 0.6 minute rise in one-way daily average commuting times across the whole country (about 2.2% of the average commute duration, which was 27.3 minutes in 2016). The association seems relatively small, but this may reflect a slow response by commuters to changes in housing costs. In effect, there may be time lags in the decisions people make about where to live and work. The association also proved to be somewhat stronger in Dublin than in the rest of the country.

6.2.4 Conclusions and policy implications

These results are consistent with the idea that high housing costs tend to push those working in urban areas into commuting greater distances. Although Ireland's rents increased unusually quickly during this period, this process may also operate in less extreme housing market conditions. This mechanism may lead to difficult policy trade-offs in the future. Both local preferences for restrictions on development in cities and national energy efficiency policies that increase the stringency of building regulations could affect the supply of housing in cities and put upwards pressure on urban housing costs. Such policies may come into conflict with other environmental and social objectives that rely on reducing commuting distances and cutting the use of fossil fuels for transport.

This research has been published in a peer-reviewed journal (see Ahrens and Lyons, 2020).

6.3 The Impact of Urban Green Space on Property Values in Ireland

6.3.1 Background

Efforts to plan liveable neighbourhoods that facilitate public health, wellbeing and social connectedness can benefit from information about the value that homebuyers place on various local amenities. Many of these spaces are in urban areas and this will increase in the future as urbanisation continues to occur around the world. Ireland has experienced some of the most rapid recent urbanisation in Europe (Ahrens and Lyons, 2019), so it is a useful place to study the valuation of urban amenities. In this study we estimate the value placed by homebuyers on urban green space, which includes managed urban parks, tree cover and more natural settings, including woodlands. These amenities can offer not only direct utility benefits, which may be captured in housing market outcomes, but also indirect positive externalities, including benefits to biodiversity, local air quality, ambient noise reduction and carbon sequestration.

This paper focuses on willingness to pay for the direct benefits of green space to households. It does this by examining the impact that urban green space amenities have on the sale price of housing, using a unique dataset of almost 40,000 real estate transactions in Dublin during the period 2010–2018. The present paper updates and extends the estimates provided for Ireland by Mayor *et al*. (2009), using not only more up-to-date transactions, but also higher resolution information on urban green space and a richer set of controls, most notably for unobserved spatial factors.

6.3.2 Data and methods

A new database of property transactions in Ireland was constructed as part of this study. The core data on transactions (the address, the contractually agreed price and the date of the transfer of real estate) are from the official Residential Property Price Register, a publicly available online register (www.propertypriceregister.ie). With the assistance of daft.ie, a leading property portal website in Ireland, these addresses were geocoded to permit linkage to digital mapping data on local amenities and other characteristics of each residence. Ireland has building-level postcodes (Eircodes), and these spatial identifiers were used to match the price register information to other spatially coded datasets.

A range of variables capturing dwelling characteristics were obtained from the Building Energy Rating (BER) database, which is maintained by the Sustainable Energy Authority of Ireland (SEAI). Ireland requires that any dwelling sold must have a standardised energy efficiency rating. These ratings are mapped onto a 15-point scale from A1 to G. BERs have been mandatory since 2007 for new dwellings and since 2009 for existing dwellings. The BER database captures extensive information on each listed property, including age, size and type of the dwelling; number

of storeys; and many attributes relevant to its energy efficiency, such as glazing and fuel type.

With the co-operation of the SEAI, the database of nearly 1 million BER certificates was collated and geocoded to building level, again using the dwellings' Eircodes. Matching to price register entries yielded a database of 39,199 property transactions in Dublin during the period 2011–2018 with linked dwelling attributes.

To measure green space amenities in the locality of each dwelling, we used the Urban Atlas provided by the EEA. This digital resource provides high-resolution land use and land cover information for cities in Europe. The Urban Atlas classifies grid squares by use, including a category for green urban areas. This category includes public green areas for mainly recreational use, such as gardens and parks. Private gardens and cemeteries are not included. The Urban Atlas provides land use classifications at a higher resolution than CORINE (Coordination of Information on the Environment) data used in most previous research on green space in Ireland. The 22 parks identified by Mayor *et al*. (2009) were selected from among the Urban Atlas green spaces and, where parks were not identifiable in the Urban Atlas dataset, polygons representing them were assembled using GIS software and satellite imagery.

To generate variables capturing the density of green space and park space around each residence in our sample, we created circular buffers with radii of 200 m and 2000 m around the dwelling locations. The proportions of these circular zones made up of green space and park space were then measured for each dwelling. This density metric is commonly used as a measure of local green space exposure in the literature on the socioeconomic effects of urban green space.

We modelled the value of a dwelling using the following regression equation:

$$\text{Price} = f(S,L,E) + \varepsilon \tag{6.1}$$

where the logged sale price of the house was taken to be a function of the house's structural characteristics (*S*; such as number of bedrooms, bathrooms and the presence of a garden), its location characteristics (*L*; such as proximity to the central business district, access to transport networks and socioeconomic factors) and its environmental characteristics (*E*; such as proximity to green spaces or the coast). The error term, ε, reflects the gap between the predicted value and the actual value. The house price was thus assumed to be a function of all of the attributes relating to the house and the resulting coefficients are the implicit marginal prices of the attributes.

More specifically, this analysis used ordinary least squares and a semi-log or log–log specification (depending on the variable), as is typical in this type of study. Allowing for the long duration of the sample, and the focus on coastal amenities, the baseline specification is, therefore, as follows:

$$\log(price_i) = \beta_0 + X'_{1i}\beta_1 + X'_{2i}\beta_2 + X'_{3i}\beta_3 + X'_{4i}\beta_4 + X'_{5i}\beta_5 + \varepsilon_i \tag{6.2}$$

where $price_i$ refers to the transacted sale price; X'_{1i} to a vector of dwelling-specific attributes; X'_{2i} to the time period (quarterly fixed effects); X'_{3i} to local market fixed effects; X'_{4i} to a vector of location-specific control amenities; and X'_{5i} to our regressors of interest, a vector of variables capturing green/park space amenities. To account for possible heteroscedasticity, robust standard errors were used when calculating statistical significance.

Dwelling-specific control variables included whether or not the property was newly built, its BER (by letter–number combination, e.g. "C2"), its floor area and footprint, the number of storeys, the building's age, glazing, insulation and fuel type, and its water and space efficiency. Location-specific control variables included distance to the following: the centre of Dublin, primary and post-primary schools, major roads, mountains, forests (by tree type), nature reserves, power lines and golf clubs. We included "blue space" controls relating to water features (see, for example, Gillespie *et al*., 2019), including distance to rivers, canals, lakes and the coastline, as well as views of the sea, rivers and lakes. The following two neighbourhood controls were also included: the fraction of people with a degree and the proportion of people who were unemployed in the dwelling's Census Small Area (SA) (an administrative unit with an average size of 100 households).

The model specifications were designed to mimic those of Mayor *et al*. (2009) to investigate the differences in estimations when a larger sample with a more detailed set of controls was used. One of the main concerns in the hedonic house price modelling literature is the issue of omitted variable bias. This can arise when a variable not available to the researchers

affects the outcome of the model and is also correlated with one or more other variables that are included in the model; it can lead to biased results for these other included variables. von Graevenitz and Panduro (2015) strongly criticise the use of spatial econometric models to address this issue. Such methods implicitly assume a structure of the unobserved effects by employing either a spatial weights matrix or a spatially fixed effect in the regressions.

von Graevenitz and Panduro (2015) propose sophisticated statistical methods to create a "flexible" fixed effect to maximise variation and minimise unobserved processes, but because of the large sample size in the present study it was not feasible computationally to apply their approach to our models. However, von Graevenitz and Panduro also conclude that a good alternative approach would be to test the sensitivity of the variables of interest by using different levels of spatial fixed effects. In the present study, we tested each specification with three different levels of spatial fixed effect. The trade-off between different scales of fixed effect is that larger spatial units allow more variation, whereas smaller units minimise the potential for unobserved processes that are correlated with the error term leading to omitted variable bias and unreliable estimates.

Three different levels of spatial controls were tested: real estate "micro markets", based on collections of named areas of the city, and two levels of official spatial units – EDs and SAs. Micro markets are likely to capture many spatially fixed factors that would otherwise not be controlled for and the 118 micro markets in our sample are similar to the 105 in Mayor *et al*. (2009). However, given the small number across the city, it is likely that they will be insufficient to address the concerns outlined in work such as that by von Graevenitz and Panduro (2015). On the other hand, although SAs have an average size of roughly 100 dwellings and are thus likely to capture very local spatial factors, such a small size means that statistical power will be challenging, with many SAs having three or fewer transactions during the period analysed. It is for this reason that EDs are our preferred specification. In total, 322 EDs are included in the dataset, compared with over 4500 SAs.

6.3.3 Results

Table 6.1 presents our regression results, distinguishing between green space and park space. Models 1, 4 and 7 included only green space controls; models 3, 6 and 9 included only park space controls; and models 2, 5 and 8 included combinations of both. The other source of variation across the models was the type of areas used in the spatial controls: models 1–3 used micro-markets, models 4–6 used EDs and models 7–9 used SAs. Other dwelling, transport, neighbourhood and blue space controls were included in the models, but have been omitted from the table for brevity.

The overall results for the two types of green space are similar in nature to the findings in Mayor *et al*. (2009): more green space, in particular parks, within a short distance of a dwelling was associated with a higher value of that dwelling. However, the magnitudes of the coefficients on parks/green space in the present study were smaller. Mayor *et al*. (2009) typically found price responses to a 10% increase in parks or green space of between 5% and 9%. We found price premia of roughly half this size and with more instances of coefficients that were insignificant or even negative.

An important difference between the two studies concerns green space other than parks. Whereas Mayor *et al*. (2009) found that a 10% increase in green space other than parks at a distance of between 0.2 km and 2 km led to a 7.6% increase in property values, the results in this study were statistically indistinguishable from zero in our preferred specification (with ED fixed effects). However, the headline finding for park space is similar across the two studies. In this study, a 10% increase in park space within 2 km of a dwelling was associated with a 5.5% increase in price, compared with a 6.7% increase in Mayor *et al*. (2009).

The differences between the two studies may stem from market conditions or from selection effects. The Mayor *et al*. (2009) study used a database for the years 2001–2006, a time of loose credit conditions, elastic supply and rapidly rising prices in the Irish housing market. Conversely, the period in this study (2010–2018) covered periods of both falling and rising prices and with tight credit conditions and an inelastic housing supply. The relationship between amenity prices and housing market conditions is an active topic of research (Gillespie *et al*., 2019) and in this regard understanding the value of green space in different market conditions is a topic worthy of future research.

It may also be the case that some of the differences in results across the two studies stem from the

Table 6.1. Regression results for models of house prices including green space density variables and other characteristics

	Fixed effects: micro market			Fixed effects: ED			Fixed effects: SA		
Variable	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**	**(9)**
Dependent variable: natural log of the transacted sale price									
Regressors of interest									
Within 2 km of Phoenix Park	–0.0338[a]	–0.0334[a]	–0.0323[a]	–0.00827	–0.00790	–0.00684	–0.00255	–0.00258	–0.00248
	(–4.64)	(–4.58)	(–4.44)	(–0.889)	(–0.85)	(–0.737)	(–0.122)	(–0.123)	(–0.119)
% green space within 200 m	–0.0181	–0.00873		–0.0130	–0.00648		–0.0354[c]	–0.0326	
	(–1.58)	(–0.769)		(–1.05)	(–0.522)		(–1.67)	(–1.53)	
% green space between 200 m and 2 km	0.0765	0.0590		0.116	0.112		–0.805[b]	–0.811[b]	
	(1.04)	(.801)		(1.22)	(1.18)		(–2.09)	(–2.1)	
% park within 200 m	–0.117[a]			–0.0936[a]			–0.0627		
	(–5.22)			(–3.91)			(–1.36)		
% park between 200 m and 2 km	0.372[a]			0.576[a]			0.339*		
	(10.5)			(10.3)			(1.68)		
% of park space within 2 km		0.339[a]			0.548[a]			0.317	
		(9.55)			(9.53)			(1.55)	
% of park/green space within 200 m			–0.0419[a]			–0.0339[a]			–0.0371[c]
			(–3.9)			(–2.94)			(–1.88)
% of park/green space within 2 km			0.322[a]			0.492[a]			0.159
			(9.45)			(9.37)			(0.819)
Controls									
Dwelling	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Transport	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Neighbourhood	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Blue space	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	39,203	39,203	39,203	39,203	39,203	39,203	39,203	39,203	39,203
R^2	0.885	0.884	0.884	0.889	0.889	0.889	0.920	0.920	0.920
RMSE	0.182	0.182	0.182	0.178	0.179	0.179	0.161	0.161	0.161

***t*-statistics are in parentheses.**

[a]***p* < 0.01.**

[b]***p* < 0.05.**

[c]***p* < 0.10.**

RMSE, root-mean-square error.

composition of transactions included. The Mayor *et al*. (2009) study used data provided by the Sherry Fitzgerald estate agency, an agency principally associated with the top end of the Dublin housing market. This is evident, for example, from Figure 2 of their study, which shows the transactions covered; the dwellings were clustered in higher value areas of the city, in particular the south and east of Dublin. Conversely, the study here used properties from all parts of the Dublin housing market. If green space is income elastic, that is, if higher income households place greater value on green space, then this would be consistent with the results in the two studies. In addition, it may be the case that green spaces are more valuable to all households, regardless of income, in higher income areas. As with the cyclicality of green space pricing, the relationship between green space and income is a useful strand of future research, which the authors have already commenced by looking at the value associated with individual green spaces.

Important exceptions to this general finding are the results for park space, either between 200 m and 2 km or within 2 km in total. There, the coefficient varied relatively substantially between the baseline and a specification with similar spatial controls but mimicking, to the greatest extent possible, the Mayor *et al*. (2009) dwelling controls. This highlights the potential correlation between dwelling characteristics, such as age, and proximity to parks.

6.3.4 Conclusions and policy implications

Our results show a statistically significant price premium for dwellings in the vicinity of parks: 10% more park space within 2 km of a dwelling is associated with a 5.5% higher price. Overall, our results imply that Dublin's parks have a value of roughly €3.4 billion capitalised into the city's housing stock, as of 2019.

There are some differences in our findings and past research by Mayor *et al*. (2009), which was based on transactions from 2001 to 2006. We found a similar premium on park space. Mayor *et al*. (2009) also found a premium on non-park green space; however, our analysis found no premium for non-park green space near a property. These differences may stem from market conditions, which changed dramatically between 2001–2006 and the period from 2010 onwards, or from selection effects, with the Mayor *et al*. (2009) database concentrating on higher value areas. In addition to incorporating more recent transactions, our dataset was sufficiently large that a more appropriate level of spatial controls can be included, while linking the dataset with BER data allowed the inclusion of important dwelling characteristics.

We can use these results to estimate the minimum value placed on Dublin parks by residential property markets. Our results indicate that 3.4% of the area within 2 km of the average dwelling in Dublin is park space. Given our valuation results, a 1% increase in park space within this range would be associated with a 0.55% increase in a property's value. This means that, for the typical home in the city, 1.9% of its value comes from parks nearby. With the average property value in Dublin totalling approximately €375,000 in 2019, parks add just over €7000 to the value of the average home. Since there are 480,000 dwellings in the capital, Dublin's parks have a value of €3361 million capitalised into the nearby housing stock. The attributed value also has fiscal significance. Local property tax is at a rate of 0.018%, implying that Dublin's local authorities receive €6 million in revenues each year as a result of the presence of park amenities.

There are limitations to this study that may be addressed with additional data and there is scope for further research to cast light on the relationships between urban green space and housing market outcomes. Our future work agenda comprises three broad strands. The first is to explore outcomes other than the transaction price, including the length of time taken to sell a property, the level of interest in a property (matching the transactions here with listings from an archive of online listings) and the gap between the listed and transaction price.

Second, it should be possible to supplement the existing analysis using additional sources of information. This includes the use of the OSI PRIME 2 database to add attributes of green space. Through the use of GIS software, each green space polygon in the Urban Atlas dataset can be categorised based on its size, its proximity to the coast, whether or not there is a cemetery on the grounds and whether or not the following features are present: water bodies (ponds, lakes, streams, rivers, canals), sports facilities,

woodlands, walking paths and playgrounds. This wealth of information poses challenges in designing the appropriate empirical specification and this work is at an early stage currently. An additional dimension along which the current specification could be supplemented include time, with conditions in the Dublin housing market varying considerably over the time covered (2010–2018). It may also be possible to add listings data covering a longer time period (from 2006), allowing a closer examination of the relationship between market conditions and willingness to pay for green space.

Lastly, the available data might allow modelling using a novel two-stage empirical approach. Specifically, a first-stage regression would estimate the value associated with each green space for which there are sufficient transactions (or listings) nearby. This would provide an estimate of the valuation of each individual green space. A second-stage regression would then use this as the outcome of interest, where the explanatory variables include both green space attributes (as described above) and sociodemographic and other factors, such as education level and age structure, in the surrounding area.

7 Recommendations

Although there is broad agreement in the scientific community on the links between poor ambient environmental conditions and population health, the mechanisms underlying such relationships are less well-established. Understanding these mechanisms is vital for the design of appropriate policy interventions.

1. The measured relationship between urban green spaces and BMI among older adults is highly sensitive to the characterisation of local green space. This suggests that there are some unobserved factors other than footpath availability that mediate the relationship between urban green space and weight status. Future work should, subject to data availability, consider factors such as inadequate lighting and restricted opening hours, which may impede the use of green spaces.
2. Related research on the links between perceptions of open space problems in one's local area and the amount of urban green space suggests that realising the full potential benefits of urban green space depends on having a safe, clean and well-serviced environment. Therefore, policy mandates or public investments in green space should also consider measures to ensure that the local area provides a safe and clean environment in which to use this green space.
3. Although levels of air pollution are relatively low in Ireland compared with many other countries and standard regulatory limits are rarely exceeded, significant links between pollution and asthma rates in the older population are still evident. This suggests that policymakers should be concerned with air pollution even at relatively low levels.

The partnership with the NBDC enabled novel research on the demographic, socioeconomic, attitudinal and health characteristics of biodiversity recorders in Ireland to be undertaken. In the next phase of this project, this sample of biodiversity recorders will be surveyed again to examine whether or not participation in biodiversity recording activities is associated with different trajectories in terms of health and wellbeing, relative to control groups from population surveys.

1. The findings show that younger people, people who live in urban areas, people who are unemployed and people with lower levels of education are all underrepresented in our sample of biodiversity recorders. This information should be used to inform recruitment into similar projects and to design research activities that maximise the potential for involving citizen scientists.

The way information is presented or "framed" affects the extent to which people attend to that information and also the choices they make. Using insights from behavioural science, the research demonstrated that people alter the importance they assign to environmental regulations depending on how the regulation is framed. Regulations motivated by preventing environmental damage were judged as more important than ones that highlighted the importance of (1) maintaining a clean environment, (2) fairness in following rules or (3) respecting Irish values and the local community. The results also show that individuals with less concern for the environment were more susceptible to these framing effects.

1. Regulations should be communicated with information specific to their role in protecting the environment and preventing any related harms to people. This approach can be used when communicating with companies of different sizes and for different types of pollution (e.g. water or air).
2. Highlighting the risks to the environment (and others) may be especially effective when communicating with individuals who are less concerned about the environment. It might be somewhat counterintuitive to suggest that harms to the environment will be an effective communication strategy for those who care less about the environment, but one possibility is that apathy is associated with less attention paid to the environment rather than active disregard for environmental harms. The findings imply that making environmental risks clear and salient on communications could counteract this lack of attention.

Understanding the effects of environmental policy on firm performance is important for the design of policy measures aimed at a more sustainable and resource-efficient production and for a wider acceptability of such measures. Based on an analysis of a range of firm-level datasets, the research provided new evidence on the effect of environmental regulations and other factors on the propensity of firms to introduce innovations with environmental benefits and the impact of these innovations on their export performance. Furthermore, it identified the determinants of firms' investments in environmental protection and the impact of these investments on a broad range of firm performance outcomes, including the growth of output, employment, productivity, export intensity and energy intensity.

1. To the extent that green innovations lead to an improved environmental quality, this evidence suggests that there could be a need for targeted policy measures to enable and foster green innovations by small and medium-sized firms. These firms are more likely than large firms to face market failures and financing constraints when they consider their engagement in R&D activity and green innovation.
2. Furthermore, the results suggest that there could be a need for targeted policy measures to enable small and medium-sized firms in particular to invest in environmental protection. The findings also suggest that facilitating learning from firms with green investments within the same industry and within the same region could foster firms' investments in environmental protection.
3. Although it was found that, in the medium term, green investments improve firm performance, it appears that not all firms benefit equally from green investments. This result suggests that in the medium term not all firms have the capacity to generate substantial benefits from green investments to outweigh the associated costs. Such benefits could be larger for all firms in the long term. A longer time series of data would allow for these issues to be further examined. To the extent that the transition to a climate-neutral economy requires increased investment in environmental protection across all firms, targeted supports to allow firms to adjust and absorb the associated costs could be beneficial.

Finally, the research examined a number of issues concerning spatial and land use planning issues. Evidence of a link between urban rents and commuting times was identified, as was a significant price premium in the Dublin area for dwellings in the vicinity of parks.

1. Further research on the policy implications arising from the link between urban rents and commuting times should be undertaken. In particular, the trade-offs between local preferences for restrictions on development in cities, national energy efficiency policies that increase the stringency of building regulations, targets for the reduction in the use of fossil fuels for transport and increased demand for remote working in the future all need to be teased out.
2. The findings on the residential price premium for Dublin parks should be extended to provide further information for urban planners tasked with the design of urban parks. Future work could also investigate the precise features of urban parks that are associated with a price premium, such as size and proximity to the coast, and whether or not the following features are present: water bodies (ponds, lakes, streams, rivers, canals), sports facilities, woodlands, walking paths and playgrounds, for example.

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Abbreviations

BER	Building Energy Rating
BMI	Body mass index
CI	Confidence interval
CIP	Census of Industrial Production
CIS	Community Innovation Survey
COVID-19	Coronavirus disease 2019
CSO	Central Statistics Office
ED	Electoral division
EEA	European Environment Agency
EPA	Environmental Protection Agency
ESRI	Economic and Social Research Institute
GIS	Geographic information system
NACE	Statistical classification of economic activities in the European Community
NBDC	National Biodiversity Data Centre
NEPS	New Environmental Paradigm Scale
OSI	Ordnance Survey Ireland
ppb	Parts per billion
R&D	Research and development
RCT	Randomised controlled trial
SA	Small Area
SEAI	Sustainable Energy Authority of Ireland
TILDA	The Irish Longitudinal Study on Ageing

AN GHNÍOMHAIREACHT UM CHAOMHNÚ COMHSHAOIL
Tá an Ghníomhaireacht um Chaomhnú Comhshaoil (GCC) freagrach as an gcomhshaol a chaomhnú agus a fheabhsú mar shócmhainn luachmhar do mhuintir na hÉireann. Táimid tiomanta do dhaoine agus don chomhshaol a chosaint ó éifeachtaí díobhálacha na radaíochta agus an truaillithe.

Is féidir obair na Gníomhaireachta a roinnt ina trí phríomhréimse:

Rialú: *Déanaimid córais éifeachtacha rialaithe agus comhlíonta comhshaoil a chur i bhfeidhm chun torthaí maithe comhshaoil a sholáthar agus chun díriú orthu siúd nach gcloíonn leis na córais sin.*

Eolas: *Soláthraímid sonraí, faisnéis agus measúnú comhshaoil atá ar ardchaighdeán, spriocdhírithe agus tráthúil chun bonn eolais a chur faoin gcinnteoireacht ar gach leibhéal.*

Tacaíocht: *Bímid ag saothrú i gcomhar le grúpaí eile chun tacú le comhshaol atá glan, táirgiúil agus cosanta go maith, agus le hiompar a chuirfidh le comhshaol inbhuanaithe.*

Ár bhFreagrachtaí

Ceadúnú
Déanaimid na gníomhaíochtaí seo a leanas a rialú ionas nach ndéanann siad dochar do shláinte an phobail ná don chomhshaol:
- saoráidí dramhaíola *(m.sh. láithreáin líonta talún, loisceoirí, stáisiúin aistrithe dramhaíola)*;
- gníomhaíochtaí tionsclaíocha ar scála mór *(m.sh. déantúsaíocht cógaisíochta, déantúsaíocht stroighne, stáisiúin chumhachta)*;
- an diantalmhaíocht *(m.sh. muca, éanlaith)*;
- úsáid shrianta agus scaoileadh rialaithe Orgánach Géinmhodhnaithe *(OGM)*;
- foinsí radaíochta ianúcháin *(m.sh. trealamh x-gha agus radaiteiripe, foinsí tionsclaíocha)*;
- áiseanna móra stórála peitril;
- scardadh dramhuisce;
- gníomhaíochtaí dumpála ar farraige.

Forfheidhmiú Náisiúnta i leith Cúrsaí Comhshaoil
- Clár náisiúnta iniúchtaí agus cigireachtaí a dhéanamh gach bliain ar shaoráidí a bhfuil ceadúnas ón nGníomhaireacht acu.
- Maoirseacht a dhéanamh ar fhreagrachtaí cosanta comhshaoil na n-údarás áitiúil.
- Caighdeán an uisce óil, arna sholáthar ag soláthraithe uisce phoiblí, a mhaoirsiú.
- Obair le húdaráis áitiúla agus le gníomhaireachtaí eile chun dul i ngleic le coireanna comhshaoil trí chomhordú a dhéanamh ar líonra forfheidhmiúcháin náisiúnta, trí dhíriú ar chiontóirí, agus trí mhaoirsiú a dhéanamh ar leasúchán.
- Cur i bhfeidhm rialachán ar nós na Rialachán um Dhramhthrealamh Leictreach agus Leictreonach (DTLL), um Shrian ar Shubstaintí Guaiseacha agus na Rialachán um rialú ar shubstaintí a ídíonn an ciseal ózóin.
- An dlí a chur orthu siúd a bhriseann dlí an chomhshaoil agus a dhéanann dochar don chomhshaol.

Bainistíocht Uisce
- Monatóireacht agus tuairisciú a dhéanamh ar cháilíocht aibhneacha, lochanna, uiscí idirchriosacha agus cósta na hÉireann, agus screamhuiscí; leibhéil uisce agus sruthanna aibhneacha a thomhas.
- Comhordú náisiúnta agus maoirsiú a dhéanamh ar an gCreat-Treoir Uisce.
- Monatóireacht agus tuairisciú a dhéanamh ar Cháilíocht an Uisce Snámha.

Monatóireacht, Anailís agus Tuairisciú ar an gComhshaol
- Monatóireacht a dhéanamh ar cháilíocht an aeir agus Treoir an AE maidir le hAer Glan don Eoraip (CAFÉ) a chur chun feidhme.
- Tuairisciú neamhspleách le cabhrú le cinnteoireacht an rialtais náisiúnta agus na n-údarás áitiúil *(m.sh. tuairisciú tréimhsiúil ar staid Chomhshaol na hÉireann agus Tuarascálacha ar Tháscairí)*.

Rialú Astaíochtaí na nGás Ceaptha Teasa in Éirinn
- Fardail agus réamh-mheastacháin na hÉireann maidir le gáis cheaptha teasa a ullmhú.
- An Treoir maidir le Trádáil Astaíochtaí a chur chun feidhme i gcomhair breis agus 100 de na táirgeoirí dé-ocsaíde carbóin is mó in Éirinn.

Taighde agus Forbairt Comhshaoil
- Taighde comhshaoil a chistiú chun brúnna a shainaithint, bonn eolais a chur faoi bheartais, agus réitigh a sholáthar i réimsí na haeráide, an uisce agus na hinbhuanaitheachta.

Measúnacht Straitéiseach Timpeallachta
- Measúnacht a dhéanamh ar thionchar pleananna agus clár beartaithe ar an gcomhshaol in Éirinn *(m.sh. mórphleananna forbartha)*.

Cosaint Raideolaíoch
- Monatóireacht a dhéanamh ar leibhéil radaíochta, measúnacht a dhéanamh ar nochtadh mhuintir na hÉireann don radaíocht ianúcháin.
- Cabhrú le pleananna náisiúnta a fhorbairt le haghaidh éigeandálaí ag eascairt as taismí núicléacha.
- Monatóireacht a dhéanamh ar fhorbairtí thar lear a bhaineann le saoráidí núicléacha agus leis an tsábháilteacht raideolaíochta.
- Sainseirbhísí cosanta ar an radaíocht a sholáthar, nó maoirsiú a dhéanamh ar sholáthar na seirbhísí sin.

Treoir, Faisnéis Inrochtana agus Oideachas
- Comhairle agus treoir a chur ar fáil d'earnáil na tionsclaíochta agus don phobal maidir le hábhair a bhaineann le caomhnú an chomhshaoil agus leis an gcosaint raideolaíoch.
- Faisnéis thráthúil ar an gcomhshaol ar a bhfuil fáil éasca a chur ar fáil chun rannpháirtíocht an phobail a spreagadh sa chinnteoireacht i ndáil leis an gcomhshaol *(m.sh. Timpeall an Tí, léarscáileanna radóin)*.
- Comhairle a chur ar fáil don Rialtas maidir le hábhair a bhaineann leis an tsábháilteacht raideolaíoch agus le cúrsaí práinnfhreagartha.
- Plean Náisiúnta Bainistíochta Dramhaíola Guaisí a fhorbairt chun dramhaíl ghuaiseach a chosc agus a bhainistiú.

Múscailt Feasachta agus Athrú Iompraíochta
- Feasacht chomhshaoil níos fearr a ghiniúint agus dul i bhfeidhm ar athrú iompraíochta dearfach trí thacú le gnóthais, le pobail agus le teaghlaigh a bheith níos éifeachtúla ar acmhainní.
- Tástáil le haghaidh radóin a chur chun cinn i dtithe agus in ionaid oibre, agus gníomhartha leasúcháin a spreagadh nuair is gá.

Bainistíocht agus struchtúr na Gníomhaireachta um Chaomhnú Comhshaoil
Tá an ghníomhaíocht á bainistiú ag Bord lánaimseartha, ar a bhfuil Ard-Stiúrthóir agus cúigear Stiúrthóirí. Déantar an obair ar fud cúig cinn d'Oifigí:
- An Oifig um Inmharthanacht Comhshaoil
- An Oifig Forfheidhmithe i leith cúrsaí Comhshaoil
- An Oifig um Fianaise is Measúnú
- Oifig um Chosaint Radaíochta agus Monatóireachta Comhshaoil
- An Oifig Cumarsáide agus Seirbhísí Corparáideacha

Tá Coiste Comhairleach ag an nGníomhaireacht le cabhrú léi. Tá dáréag comhaltaí air agus tagann siad le chéile go rialta le plé a dhéanamh ar ábhair imní agus le comhairle a chur ar an mBord.

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Research on the Environment, Health, Consumer Behaviour and the Economy: ESRI Environment Research Programme 2018-2020

Editor: Anne Nolan. Authors: Achim Ahrens, Peter Barlow, Brian Broderick, Philip Carthy, Aoife Donnelly, Tom Gillespie, Martina Hennessy, Ronan Lyons, Seán Lyons, Pete Lunn, Ciarán Mac Domhnaill, Finn McLaughlin, Stefano Meneto, Frank Moriarty, Owen Naughton, Anne Nolan, Aonghus O´Domhnaill, Margaret O'Mahony, Deirdre Robertson, Iulia Siedschlag, Shane Timmons, Manuel Tong Koecklin and Weijie Yan

Identifying Pressures

The Environmental Protection Agency/Economic and Social Research Institute Environment Research Programme brings together a diverse set of research topics with the objective of assessing the ways in which the environment interacts with economic and social processes. This report provides a detailed summary of the 12 topics examined in the second phase of the programme, which was carried out between 2018 and 2020. These topics can be grouped into five broad themes:

1. examining the impact of the environment on health and wellbeing;
2. characteristics of biodiversity data recorders;
3. using behavioural science to design and test behaviourally informed regulatory communications;
4. examining the drivers and consequences of green innovations and green investments;
5. investigating land use and spatial planning issues.

Informing Policy

The research identified strong links between environmental conditions and health and wellbeing. In particular, living in areas with higher levels of NO2 pollution was associated with higher rates of asthma in people aged 50 and over. It is notable that an effect was found even though standard regulatory limits are rarely exceeded in Ireland.

Evidence of an association between high housing costs and longer commuting distances was identified. This implies potentially difficult policy trade-offs; for example, local preferences for restrictions on development in cities could affect the supply of housing in cities. However, the linkage between urban rents and commuting distances may be weakened if there is a sustained shift towards remote working in the future.

The research showed that environmental quality and firm performance go together. Policy-induced green innovations are beneficial for firms' international competitiveness. In the medium term, firms' investments in environmental protection increase their performance. However, not all firms benefit equally from green investments. Taken together, these results suggest that targeted policy measures to enable small and medium-sized firms in particular to invest in environmental protection could be beneficial.

Developing Solutions

Findings from the studies that examined the social and economic aspects of urban green space suggest that the design of urban green spaces should consider not only the quantity and accessibility of urban green space but also the wider characteristics of the area, such as cleanliness and safety, that encourage the use of urban green space.

A study of newly recruited biodiversity data recorders, carried out in partnership with the National Biodiversity Data Centre, showed that the biodiversity data recorders were more socioeconomically advantaged, more engaged in environmental protection and more physically active than the general population. These insights can help in recruitment campaigns and in designing research activities that involve citizen scientists.

The results from the behavioural science strand established that the importance assigned to different environmental regulations can be altered by the language used to present them. Framing regulations as preventing environmental damage was the most effective strategy, particularly among individuals who are less likely to consider environmental harms. These results imply that the communication strategies should highlight the function of regulations rather than appeal to other rationales (such as protecting Irish values).

EPA Research: McCumiskey House, Richiew, Clonskeagh, Dublin 14.

Phone: 01 268 0100
Twitter: @EPAResearchNews
Email: research@epa.ie

www.epa.ie

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