The Economic and Social Review, Vol. 54, No. 1 Spring 2023, pp. 29-75

POLICY PAPER

Assessing the Impact of Mobility on COVID-19: Spatial Evidence from Ireland

Cathal O'Donoghue
University of Galway

Cathal Geoghegan*
University of Galway

Ruth Kelly
University of Galway

Paul Kilgarriff
Luxembourg Institute of Socio-Economic Research

Abstract: This paper attempts to draw lessons from the Irish experience of COVID-19 by concentrating on the importance of mobility, especially the role of commuting. As lockdown periods progressed, we found increasing levels of workplace attendance, over and above what would be expected if only essential workers were physically going to work. Mobility-related variables were significantly associated with increased incidence of the virus at a national level. The level of inter-county essential worker commuting was found to be inversely related to infection rates in the workers' home county.

I INTRODUCTION

The COVID-19 pandemic has seen a period of disruption to daily lives unprecedented in modern times. By August 2021, over 4.3 million people had died[1] as a result of the virus despite the introduction of numerous

Acknowledgements: The Authors are grateful to the Irish Health Research Board and Irish Research Council for funding of this research. The authors are solely responsible for the content and the views expressed.

* Corresponding author: cathal.c.geoghegan@nuigalway.ie

[1] As of August 11, 2021: https://coronavirus.jhu.edu/.

non-pharmaceutical interventions (NPIs) in many countries such as stay-at-home orders, school closures and non-essential business closures, as well as the development and dissemination of multiple vaccines. The pandemic has also wrought great economic damage with large decreases in global economic activity and employment, especially following the introduction of lockdowns by many countries in March 2020.

Lockdown measures aim to limit social interactions by reducing mobility levels amongst the population, thereby giving the virus fewer opportunities to spread between individuals. Mobile phone data have been put forward as a way to capture population mobility in real time, thus providing a measure of compliance with lockdown rules (Charoenwong *et al*., 2020; Shearston *et al*., 2021). Studies have found a connection between the spread of COVID-19 and the frequency or duration of trips to specific sites such as workplaces, restaurants, and shops (Bryant and Elofsson, 2020; Rahman *et al*., 2020). The size of decrease in commuting mobility has been associated with the local prevalence of COVID-19, with greater falls in mobility being associated with lower prevalence (Kissler *et al*., 2020). While attention has been paid in the literature to the role of decreased commuting early in the pandemic, the role of shifting commuting patterns as the pandemic has progressed has yet to be studied in depth.

This paper assesses the factors that have influenced the spread of the virus in Ireland, with a particular emphasis on the impact of mobility. We examine how commuting patterns have changed over the course of the pandemic, especially in relation to the number of essential workers in the economy. Using CSO Place of Work, School or College Census of Anonymised Records (POWSCAR) and Google Community Mobility data, we assess the spread of the virus across county boundaries and ask whether geographical proximity or commuting across county lines had a greater influence on the incidence rate of COVID-19. We also investigate the relationship between COVID-19 in Northern Ireland and the incidence rate of the virus in border regions of the Republic of Ireland.

Boudou *et al*. (2021) study the impact of individual NPI phases in the Republic of Ireland on COVID-19 transmission patterns. Using segmented modelling via breakpoint regression, the authors find that moderately strict NPIs were more effective at reducing the transmission of the virus than the strictest 'lockdown' level of NPIs. Divergences were observed across population sub-groups with lagged response times to NPIs being observed among populations over 80 years, residents of rural/commuter regions, and cases associated with a below-median deprivation score.

McAloon *et al*. (2021) also examine the impact of NPIs in Ireland, using national contact tracing data. The authors find that the number of contacts per case from May to December 2020 was overdispersed, that the mean varied considerably over time and that contacts per case were temporally associated with government interventions. The mean number of contacts per case during the lowest level of government contact restrictions (July to mid-September 2020) was two to three

times more than at the highest level of restriction (Stay at home phase, beginning of May 2020).

Grannell and Grannell (2020) use a two-region SEIR (Susceptible-Exposed-Infected-Recovered) model to explore the model to explore the evolution of the pandemic in the Republic of Ireland and Northern Ireland. The model actually consists of an SEIR model for each country, which are linked through border interaction terms. They find that the pursuit of different policies to control the virus in the two parts of Ireland, in the presence of an open border, could result in substantial negative effects on either side of the border.

Multiple aspects of the economic impact of the virus have been studied thus far, especially during the first wave of the pandemic. Sizable falls in GDP were seen during the first two quarters of the year, although a large rebound in economic activity occurred in Q3 following the easing of restrictions (CSO, 2020). Despite a drop in personal consumption expenditure that is one of the highest in Europe, the concentration of Irish exports in computer services and pharmaceutical and medicinal goods ensured that overall GDP impact was much more muted due to the growth in these export products (O'Toole, 2020). Job losses as a result of the pandemic were concentrated in the accommodation, food services, and retail sectors with younger workers and those in the lowest income quintiles most affected (Byrne *et al*., 2020).

O'Donoghue *et al*. (2020) examine the distributional impact of the pandemic in Ireland. They find that a combination of crisis-induced income-support policy innovations and existing progressive elements of the tax-benefit system were effective in mitigating an increase in income inequality in the first wave of the pandemic, with the poorest 60 per cent of households improving their financial situation under the policy measures introduced during the crisis. A study of essential workers[2] found that such workers made up 22 per cent of all employees in Ireland during the pandemic's first wave, were more likely to be female (almost 70 per cent), and were concentrated in lower paid occupations (Redmond and McGuinness, 2020a).

This paper attempts to answer the following questions in the Irish context:

- To what extent does mobility, and particularly cross-county commuting, impact the spread of COVID-19?
- What is the relationship between the incidence of COVID-19 in the border counties of the Republic of Ireland and Northern Ireland?
- How compliant were Irish workers with lockdown restrictions?

The paper is laid out as follows. First, the context of the pandemic in Ireland is outlined, presenting how case numbers and deaths have risen and how the economy has been impacted since March 2020. The methodology and data section describes

[2] Workers who perform critical functions that are key to maintaining the functioning of the heath system, economy, and society (Redmond and McGuinness, 2020a).

the COVID-19 case data, employment data, mobility data, NPIs and IO methodology. The main results are presented in Sections IV to VII, while Section VIII contains a discussion of the paper's results.

II CONTEXT

From an Irish perspective, the pandemic has been characterised by four waves. The first wave began with the confirmation of the first case of the virus in the Republic of Ireland on 29 February 2020.[3] Cases continued to increase through March and April, reaching a peak of 936 new cases on 23 April. Confirmed COVID-19 deaths peaked during the first wave at 77 on 20 April. By 23 April, total confirmed cases were at 17,607 and total confirmed deaths were at 794. Long-term residential settings were heavily impacted during the first wave, with 257 clusters in nursing homes and 184 in residential settings up to July 2020 (Kennelly *et al*., 2020).[4] As a result, nursing homes saw a much higher rate of unexpected death in this period compared with previous years (HIQA, 2020).

Due to lockdown measures, the first wave subsided with new cases eventually reaching single figures by mid-June. Following a steady increase in cases through August and September, the second wave of the virus became apparent in October with new daily cases peaking at 1,283 on 18 October, precipitating a second lockdown. New cases once again fell, dropping to a low of 183 cases on 3 December. Following a relaxation of restrictions for the Christmas period, a third wave of the virus developed with the largest number of cases yet seen in the country. New cases peaked at 8,248 on 8 January 2021, bringing cumulative confirmed cases to 127,637 and 2,327 deaths. New case numbers fell quickly from this point, reaching 1,000 new cases per day by early February, with a more gradual decline following in the rest of February. By March to May 2021, daily new case numbers continued to fall slowly with an average of just over 400 cases per day by mid-May. A ransomware attack on the Health Service Executive on 14 May temporarily halted the ability of the government to collect and release detailed COVID-19 statistics.

The increasing incidence of the Delta variant led to a fourth wave of the virus, with cases increasing from July 2021, reaching a level between 1,000 and 2,000 cases per day over late summer and autumn. Over winter 2021, cases continued to increase, with the first case of the Omicron variant being confirmed on 1 December.

[3] National case and death data taken from COVID-19 HPSC Detailed Statistics Profile (https://opendata-geohive.hub.arcgis.com/datasets/d8eb52d56273413b84b0187a4e9117be_0.csv?outSR=%7B%22latestWkid%22%3A3857%2C%22wkid%22%3A102100%7D) on data.gov.ie website. These figures may not correspond with official Central Statistics Office (CSO) data due to data updates and revisions, differing categorisations of underlying cause of death, date of death vs. date of reporting etc.

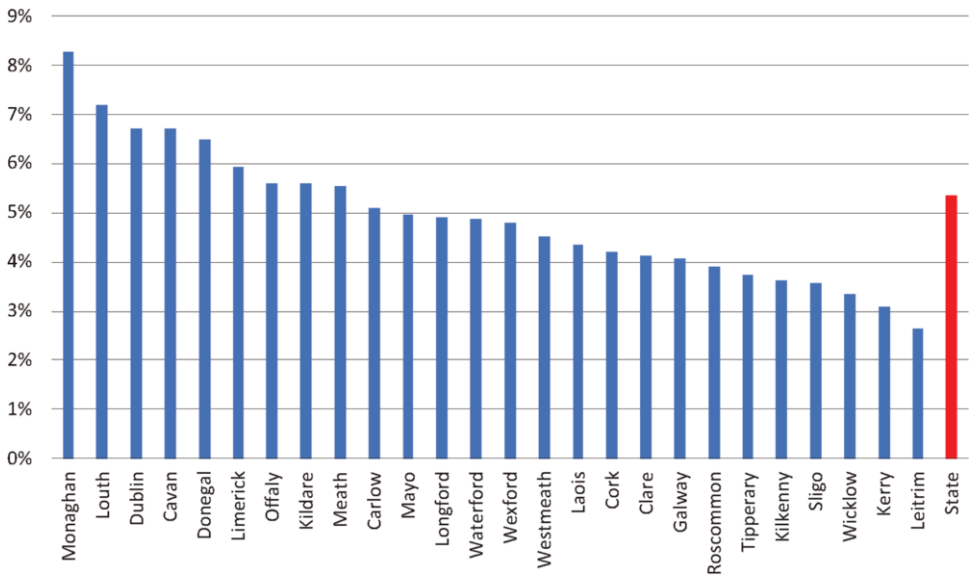
[4] Clusters are defined as two or more cases in a single location.

Case numbers increased rapidly over December and early January, peaking at 26,122 reported cases on 8 January, 2022. Cases fell sharply after the 8 January peak, and on 21 January Taoiseach Micheál Martin announced the easing of almost all COVID-19 restrictions.

Despite the small geographical size of Ireland, variable levels of infection were seen in different counties, leading to localised restrictions being enforced at various points during the pandemic. Increased restrictions were seen in August 2020 in Kildare, Offaly, and Laois following a spike in cases in the region, lasting two weeks in Offaly and Laois, and four weeks in Kildare. Level 3 restrictions were imposed in Donegal in late September 2020, increasing to Level 4 on 15 October along with Cavan and Monaghan. The whole country went into lockdown on 21 October.

The relatively large variability in the number of cases per county can be observed in Figure 1. The county with the highest number of cases per head of county population is Monaghan which has seen 8.27 per cent of its population reporting cases over the course of the pandemic to mid-May 2021. Four of the top five counties in case numbers per head of county population share a border with Northern Ireland (Monaghan, Louth, Cavan, and Donegal). The county with the lowest relative number of cases is Leitrim with 2.65 per cent of its population infected. The proportion of COVID-19 cases per capita for the Republic of Ireland as a whole is 5.33 per cent.

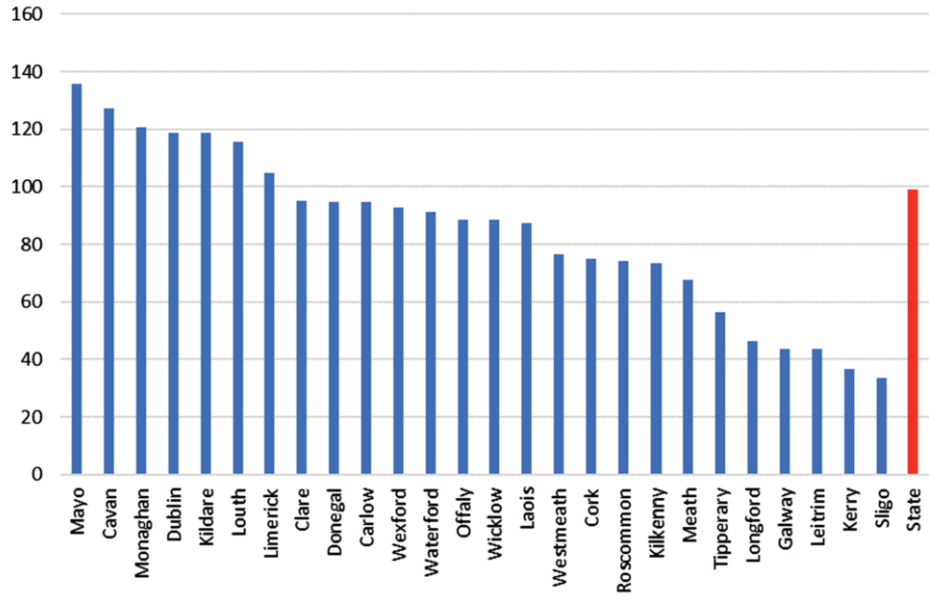
Figure 1: Incidence Rate of COVID-19 by County Population (March 2020 – May 2021)



Source: COVID-19 HPSC Detailed Statistics Profile.

The number of deaths per 100k people on a per county basis is seen in Figure 2. Despite having the 11th highest number of cases per 100k people, Mayo has the highest number of deaths by the same measure with 136 deaths per 100k. The border counties that ranked highly in cumulative cases also figure highly in the number of deaths with Cavan, Monaghan and Louth having the second, third and sixth highest death rates respectively. Sligo has the lowest death rate with 34 deaths per 100k people. The average COVID-19 death rate for the State as a whole is 99 deaths per 100k people.

Figure 2: Deaths of Individuals with COVID-19 by County per 100k Population (March 2020 – May 2021)



Source: Central Statistics Office.[5]

Ireland's policy approach to the COVID-19 crisis has been multidimensional, involving measures to 1) limit the spread of the virus in the community and specific institutional settings, 2) test and trace specific contacts, 3) ensure that there were adequate healthcare services and equipment for patients suffering from the virus, and 4) limit the financial burden on individuals and business due to the response to the virus (Kennelly *et al*., 2020).

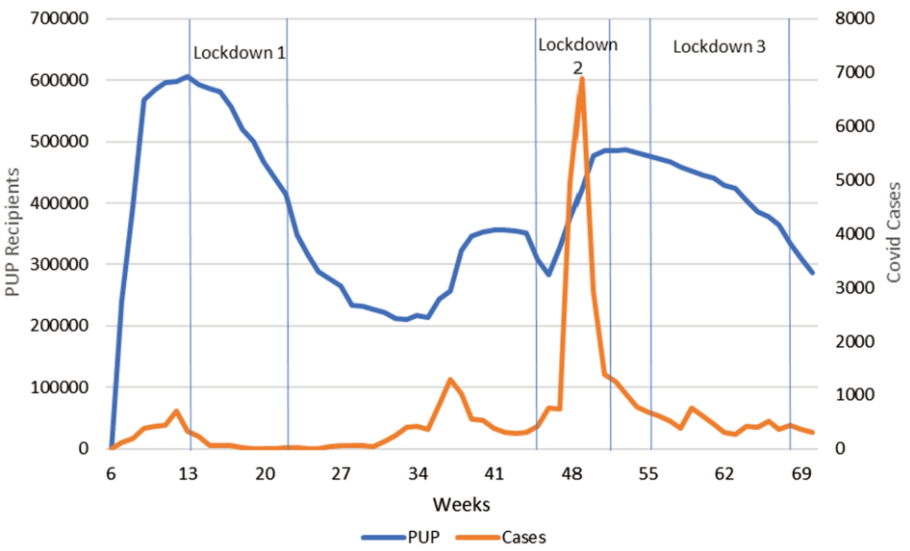
Ireland's most significant policy response to the virus has been the utilisation of measures designed to limit social interaction through reducing population

[5] County-level death data taken from Central Statistics Office website (https://www.cso.ie/en/statistics/health/covid-19deathsandcasesstatistics/).

mobility. These measures have included the closure of schools and businesses, banning visits to other households and limits on the distance people could travel from their home. The restrictiveness of these measures was reflected in a levels-based framework introduced by the government as part of the reopening of society following the first lockdown in May 2020. The measures outlined in the framework ranged from Level 1 (least restrictive) to Level 5 (most restrictive). As the pandemic has evolved, a pattern has emerged of more restrictive measures being adopted to combat rising case numbers followed by an easing of restrictions when case numbers fall to an acceptable level.

The Irish government's economic response to the crisis has concentrated on reducing the impact of COVID-19 restriction on household incomes and on helping businesses and firms survive the pandemic period. Income support measures include the Pandemic Unemployment Payment (PUP) for individuals who lose their job as a result of the pandemic and the Temporary Wage Subsidy Scheme (TWSS) where a proportion of employee earnings are subsidised by the State in order to incentivise employers to maintain their work force (O'Donoghue *et al*., 2020) (see Figure 1). The PUP provided a maximum payment of €350 per week, available to workers who have lost their job on (or after) 13 March 2020 due to the COVID-19 crisis. The TWSS was replaced by the Employment Wage Subsidy Scheme on 1 September 2020 which provided a flat-rate subsidy per week based on the number of qualifying employees on the payroll and employee earnings. Outside of these supports, other measures introduced include payment breaks on mortgage, personal

Figure 3: COVID Caseload and the Number of Recipients of Pandemic Unemployment Payment



Source: Central Statistics Office; COVID-19 HPSC Detailed Statistics Profile.

and business loans, liquidity funding for businesses, guaranteed loan schemes, deferred tax payments, a reduction in the rate of VAT as well as moratoriums on evictions and rent increases (Kennelly *et al*., 2020).

Despite the impact of COVID-19, Irish GDP grew by 3.4 per cent in 2020 (CSO, 2021a). However, this figure is heavily influenced by the activity of multinationals in Ireland, as shown by 5.4 per cent decrease in the Modified Domestic Demand (MDD) which excludes globalisation effects such as trade in intellectual property. These figures outperformed government forecasts which in April 2020 predicted a 10.5 per cent fall in GDP, as well as a 15.1 per cent drop in MDD (Department of Finance, 2020). By April 2021, around 420,000 people were in receipt of the COVID-19 PUP, which was 28 per cent lower than the peak figure reached in April 2020. Between the PUP, those on the Live Register and employees benefiting from the Employment Wage Subsidy Scheme, around 912,000 people were in receipt of some form of income support in April 2021 (Department of Finance, 2021).

III METHODOLOGY AND DATA

This section provides an overview of the data underlying our analysis. We utilise four main types of data; weekly counts of COVID-19 cases in the Republic of Ireland and Northern Ireland; weekly measures of employment and pandemic related income supports; weekly measures of mobility; and information on NPIs and essential workers adopted by the Irish government.

3.1 COVID Case Data

In the Republic of Ireland, daily statistics for confirmed COVID-19 cases and deaths at the county level are released by the Health Protection and Surveillance Centre (HSPC). Since August 2020, COVID-19 case statistics have also been available at the local electoral area (LEA) level. A 14-day rolling average is calculated to give the 14-day incidence rate per 100k population. Daily statistics for confirmed cases and deaths from COVID-19 in Northern Ireland are retrieved from the Northern Ireland Department of Health. The Northern Irish data are released at the local government district (LGD)[6] level.

3.2 Employment Data

Weekly data regarding the number of individuals receiving the Pandemic Unemployment Payment or the COVID Enhanced Illness Benefit[7] are drawn from

[6] There are 11 LGDs in Northern Ireland: Antrim and Newtownabbey; Ards and North Down; Armagh City, Banbridge and Craigavon; Belfast; Causeway Coast and Glens; Derry and Strabane; Fermanagh and Omagh; Lisburn and Castlereagh; Mid and East Antrim; Mid Ulster; and Newry, Mourne and Down.

[7] If a worker is told to self-isolate, restrict their movements or is diagnosed with COVID-19, they can apply for a COVID-19 Enhanced Illness Benefit payment of €350 per week.

Live Register figures provided by the Central Statistics Office (CSO). Using Census 2016 and the most recent Labour Force Survey data, those receiving COVID-related benefits are assigned to one of 17 NACE economic sectors (see Table 6 in Section 8 for sectors used).

3.3 Mobility Data

In order to measure mobility levels over the course of the pandemic, we use data from Google Community Mobility Reports.[8] In Ireland, the Community Mobility Reports use anonymised mobile phone data to show movement trends by county, across different categories of places. Six location categories are available: grocery and pharmacy; retail and recreation; parks; transit stations; workplaces; and residential. The data show how visits to (or time spent in for residential locations) categorised locations change compared to baseline days. A baseline day represents a normal value for that day of the week. The baseline day is the median value from the five week period January 3 to February 6, 2020. We use workplace attendance data as a measure of compliance with NPIs over the course of the pandemic. Commuting data are sourced from POWSCAR.[9] POWSCAR contains data for the 2016 Census for the place of work or location of school/college of all residents of the Republic of Ireland.

3.4 Non-Pharmaceutical Interventions

The public health policy response to the pandemic in Ireland has been characterised by repeated periods of easing and tightening of restrictions (see Table 1). The most significant interventions have been the imposition of three 'lockdowns', where people were required to stay within 2km of home (5km in lockdown 2 and 3), all non-essential businesses were closed, and household mixing was not permitted. These lockdowns occurred in March 2020 following the initial spread of the virus to Ireland, October 2020 following a period of gradually increasing incidence rate and December 2020 after the Christmas period saw a dramatic increase in COVID-19 case numbers. A full list of the key public health NPIs implemented by the Irish government over the course of the pandemic can be found in the Annex in Table A.1.

Three major types of NPI measures were identified by Arnon *et al*. (2020): school closures; stay-at-home orders and closure of non-essential businesses. Regarding school closures, lockdowns 1 and 3 saw primary and secondary schools being closed while all schools remained open during lockdown 2. Stay-at-home orders were issued during each lockdown, although the distance one was permitted to travel from home for exercise purposes was extended from 2km during lockdown 1 to 5km during lockdowns 2 and 3. Non-essential businesses were closed during

[8] www.google.com/covid19/mobility/.
[9] www.cso.ie/en/census/census2016reports/powscar/.

Table 1: Key Non-pharmaceutical Intervention Phases in Ireland During the COVID-19 Pandemic

Date	*Intervention Phase*	*Tightening/Easing*
27/3/20	First lockdown introduced	Tightening
18/5/20	Phase 1 of reopening	Easing
8/6/20	Phase 2 of reopening	Easing
25/6/20	Phase 3 of reopening	Easing
21/10/20	Second lockdown introduced	Tightening
1/12/20-4/12/20	Reopening of retail and hospitality	Easing
18/12/20	Intercounty travel allowed	Easing
24/12/20	Third lockdown introduced	Tightening

Source: Department of Health.

each lockdown but small changes in which businesses were considered essential were made by the government with an expansion in the number of essential businesses being seen for lockdowns 2 and 3 (see Annex for details of essential sectors and businesses in each lockdown).

3.5 Essential Workers

In order to identify essential workers, multiple sources of data are utilised. First, information from Redmond and McGuinness (2020a) is used to identify the proportion of essential workers in the healthcare, defence and public administration, retail, and transport sectors. For all other sectors of the economy, government documentation was consulted to determine which elements of each economic sector were considered essential (see Annex for a full list of essential sectors and businesses in each lockdown). For these sectors, data from the CSO were used to identify the proportion of workers in each sector who were not receiving the Pandemic Unemployment Payment or COVID Enhanced Illness Benefit. Data from the 2016 Census and the latest Labour Force Survey were then utilised to determine the proportion of these workers who were working in essential segments of each economic sector.

IV RESULTS I – COMMUTING PATTERNS

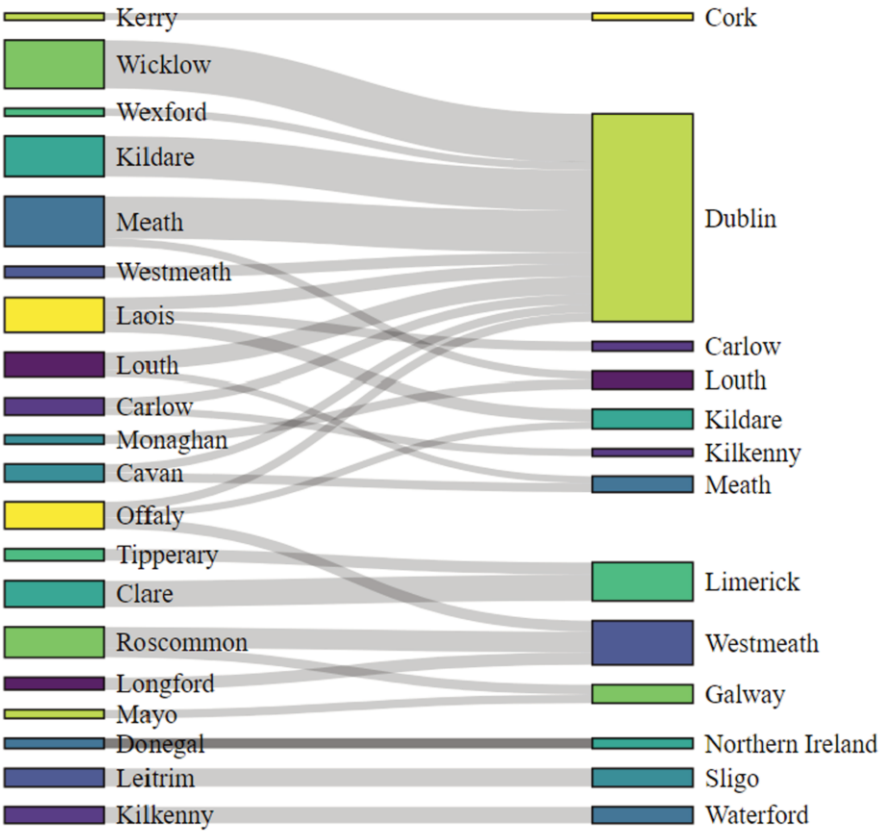
To understand the spread of the virus we consider the spatial relationship between counties. This relationship may be contiguous (share a border) or functional (commuting from location *i* to location *j*). Using POWSCAR data from 2016,[10] we

[10] Although the 2016 data are four to five years older than the pandemic time period, and as a result may not be completely accurate, commuting patterns change slowly so the 2016 data should give a good approximation of pre-pandemic mobility.

examine the functional relationship between counties. We calculate the total flow of commuters from the origin county to the destination county as a share of total origin county commuters. Figure 4 shows the flows that are greater than 5 per cent of all origin county commuters.[11] The figure shows the counties which have the strongest functional relationships. Dublin is the county that has the strongest functional relationships with large quantities of inward commuting from Wicklow, Kildare, Laois, and Meath in particular. Westmeath also has considerable inward commuters from Offaly, Roscommon, and Longford. This highlights the importance of regional centres outside of the major cities. In relation to the border region, only Donegal shows up as having a significant number of outward commuters.

Figure 4 shows the importance of studying functional relationships compared to examining which counties are neighbours and share a border. This is particularly the case in relation to Cork where only Kerry shows up as having a large number

Figure 4: Sankey Plot of County Commuter Flows – Origin (left) Destination (right)



Source: CSO POWSCAR 2016; author calculations.

[11] A table of all inter-county commuter flows is available in the Annex.

of commuters between the counties with Limerick, Tipperary, and Waterford falling below the threshold of 5 per cent of commuters. Additionally, for Northern Ireland, only the flows between NI and Donegal are sufficiently large to be counted by our analysis. We recognise that local mobility around county borders occurs, however given the relatively short distances that would be involved they are difficult to analyse.

Based on the commuting patterns observed in Figure 4, we examine the relationship between the incidence rate of the virus for commuting counties over the course of the pandemic. The results are shown in Table 2.

Table 2: Predictors of COVID-19 Incidence-Rate in Commuting Counties (April 2020 – May 2021)

	Coef.	*Std. Err.*	*t*	*P>t*
Infection rate (destination county)	0.69	0.01	71.42	0.00
Infection rate (destination county) – 7-day lag	0.18	0.01	13.74	0.00
Infection rate (destination county) – 14-day lag	–0.08	0.01	–8.23	0.00
Essential commuters from origin county	–0.0001	0.00002	–5.25	0.00
Lockdown 1	0.11	0.37	0.30	0.76
Lockdown 2	0.29	0.39	0.73	0.46
Lockdown 3	1.04	0.35	2.99	0.00
Constant	0.99	0.19	5.15	0.00
R-squared	0.78			

Source: Authors' calculations based on CSO POWSCAR 2016, COVID-19 HPSC Detailed Statistics Profile.

As would be expected in a small country such as Ireland, there is a very strong positive relationship between the incidence rate in origin and destination commuting counties. Lag-terms show a positive relationship between infection rates using a seven-day lag and a negative relationship using a 14-day lag. The changing relationship between seven and 14 days may be due to changing public behaviour as infection rates rise in nearby and commuting locations.

Surprisingly, there is a significant, negative relationship between commuting essential workers and infection rates in the commuting workers origin county. This implies that as the number of essential workers commuting to another county increases, the infection rate in their origin county drops. Dummy variables representing the first three lockdown periods (March-May 2020, October-November 2020, December 2020-April 2021) show no significant relationship between lockdowns 1 and 2 and the infection rate in out-commuting counties, and a significant, positive relationship for lockdown 3. The relationship between lockdowns and infection rate for the entire country is examined late in this paper in Table 4.

V RESULTS II – CROSS-BORDER INCIDENCE RATE

Given the level of cross-border activity between the Republic of Ireland and Northern Ireland, spatial analysis of the spread of the virus should explore the relationship between the prevalence of COVID-19 in the two countries. The relationship between the 14-day incidence rate of the virus in local electoral areas (LEAs) in the Republic of Ireland within 50km of the border and the closest local government district (LGD) in Northern Ireland is shown in Table 3.[12] As LEA data are only available from August 2020 onward, the incidence rates are only compared from 15 August 2020 to 10 May 2021.

Table 3: Predictors of COVID-19 Incidence-Rate in Border Areas (August 2020 – May 2021)

	Coef.	*Std. Err.*	*t*	*P>t*
Infection rate (Northern Ireland)	–4.27	0.91	–4.71	0.00
Infection rate (Northern Ireland) – 7-day lag	17.28	1.52	11.36	0.00
Infection rate (Northern Ireland) – 14-day lag	–2.39	0.96	–2.50	0.01
Essential commuters from origin LEA	–0.004	0.005	–0.85	0.40
Lockdown 2	–174.52	23.42	–7.45	0.00
Lockdown 3	150.52	17.37	8.67	0.00
Constant	1.85	12.19	0.15	0.15
R-squared	0.55			

Source: Authors' calculations based on CSO POWSCAR 2016, COVID-19 HPSC Detailed Statistics Profile, Northern Ireland Department of Health.

The results show a significant negative relationship between the concurrent infection rate in border LEAs and LGDs. However, this relationship is reversed when the Northern Irish infection rate is lagged by seven days, implying that changes in the infection rate in Northern Irish LGDs may anticipate changes in border LEAs south of the border. Similar to the results in Table 2, a negative relationship between infection rates becomes apparent when a 14-day lag is applied to the infection rate in Northern Ireland.

There is no significant relationship between the number of commuters who are essential workers travelling from an Irish LEA to a Northern Irish LGD and the infection rate in the Republic of Ireland. Given the very low levels of commuter flow over the border from south to north, this is not an unexpected finding. Donegal is the only county where more than 5 per cent of commuter traffic goes to Northern Ireland, with most of that traffic coming from a single LEA, Buncrana. With

[12] The full list of border LEAs and Northern Irish LGDs is available in Table 12 of the Annex.

essential workers being a fraction of the overall workforce,[13] an even smaller flow of traffic from south to north would have occurred.

As LEA-level data are available from August 2020 onwards, only dummy variables for lockdowns 2 and 3 are included in the analysis. The results indicate a negative relationship between infection rates in Northern Irish border LGDs and the LEAs in the Republic of Ireland in lockdown 2, and a positive relationship in lockdown 3. However, these results are likely more indicative of the overall infection rates in the two nations at these times, rather than any specific aspect related to the border areas.

VI RESULTS III – WORK AND MOBILITY

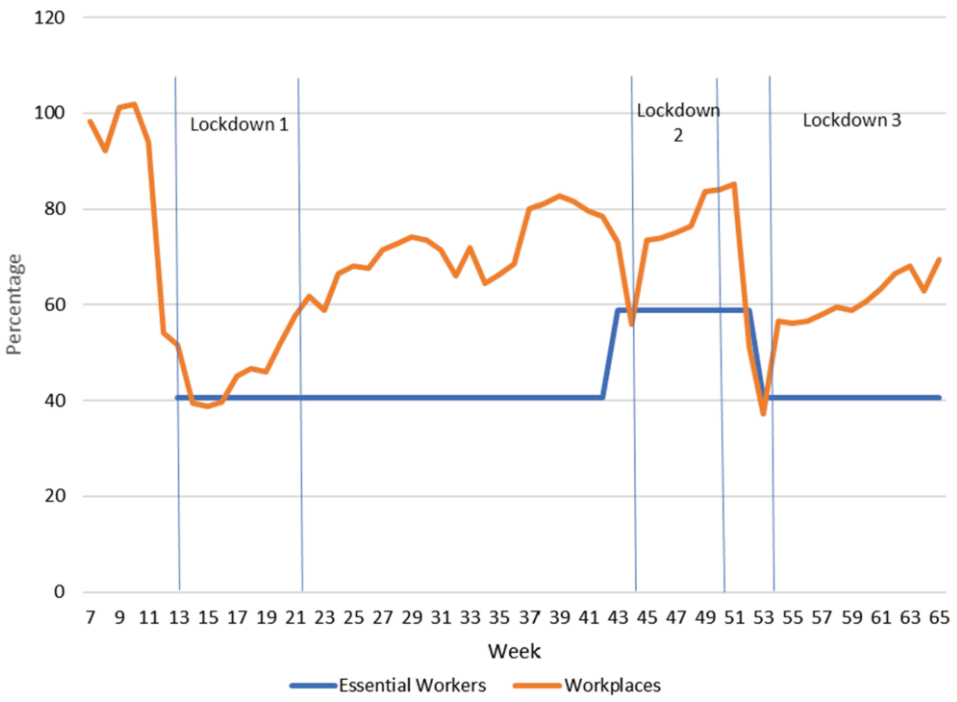
This paper examines workplace attendance as a proxy for compliance with COVID-19 mobility restrictions, especially during periods of lockdown. During these periods, government advice has been that only essential workers should physically attend their workplace with all other workers working from home if possible. The degree to which that advice was followed in shown in Figure 5.

The graph shows the overall percentage of workers that are considered essential by the Irish government and the level of workplace attendance using Google Community Mobility Reports data compared with the baseline period between January 3 and February 6, 2020. During lockdown 1, we estimate that 41 per cent of all workers in the economy were considered essential. During lockdown 2, education and construction workers, as well an expanded number of workers from other sectors, are now considered essential. As a result, the estimated proportion of essential workers rises to 58 per cent of all workers. During lockdown 3, schools and construction are once again closed so the proportion of essential workers returns to that seen during the first lockdown.

Workplace attendance begins to drop prior to the imposition of the first lockdown, reaching levels commensurate with the overall proportion of essential workers in the economy after the lockdown begins. After three weeks of lockdown, workplace attendance begins to increase above essential worker level and continues to rise so that workplace attendance in the last week of lockdown 1 is at 52 per cent of pre-crisis levels. Workplace attendance continues to rise as restrictions are eased over the summer months, reaching 83 per cent of pre-crisis levels in early September as schools reopen.

[13] Essential workers in Ireland averaged 40.5 per cent of the workforce in lockdowns 1 and 3, and 59 per cent in lockdown 2. Spatially, essential worker shares were quite equal by county with the lowest being 39.1 per cent in Leitrim during lockdowns 1 and 3 and the highest being 42.1 per cent in Galway. During lockdown 2, in which essential workers were more widely defined due to schools remaining open, Leitrim was again lowest with 57.1 per cent and Galway again highest with 61.2 per cent.

Figure 5: Workplace Attendance and Essential Workers During the COVID-19 Pandemic

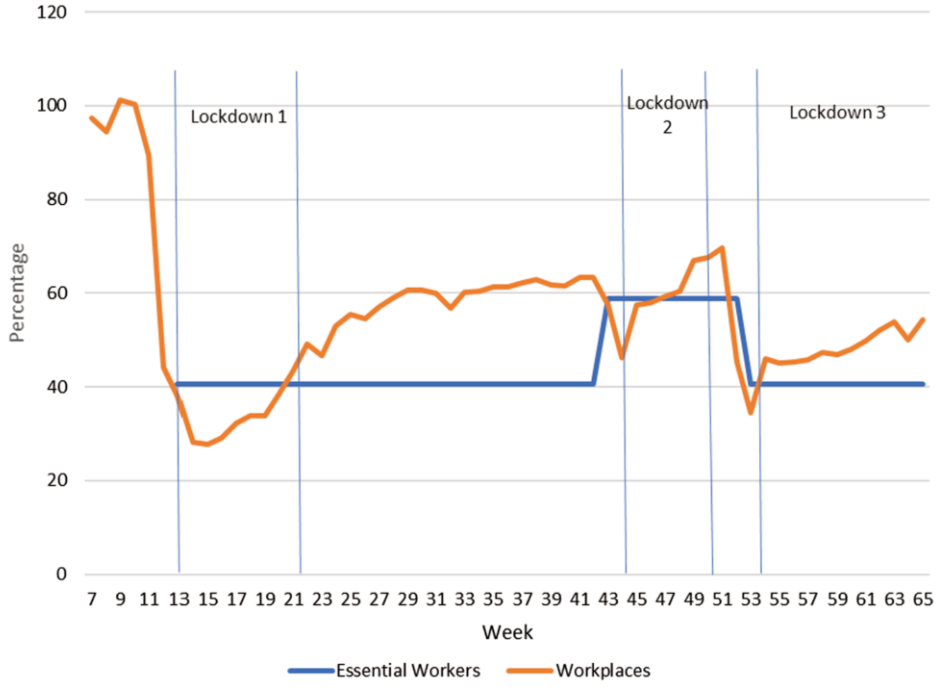


Source: Authors' calculations based on COVID-19 HPSC Detailed Statistics Profile, Google COVID-19 Community Mobility Reports, CSO POWSCAR 2016.

During lockdown 2, workplace attendance falls to levels associated with essential worker workplace attendance for a single week after the lockdown is introduced before rising back to near pre-lockdown levels for the remainder of the lockdown period. Lockdown 3 also sees a brief fall in workplace attendance to levels commensurate with essential workplace attendance before rising to 56 per cent of pre-crisis levels and gradually increasing from there over the course of the lockdown period.

The pattern of workplace attendance seen in Figure 5 is very similar to that seen in individual counties across the country with exception of Dublin which is shown in Figure 6. Compared with the country as a whole, workplace attendance fell further below that associated with essential workplace attendance during lockdown 1 and did not increase above essential worker level until the lockdown ended. A similar pattern can be seen during lockdown 2. Workplace attendance during the third lockdown has risen above essential worker level but the gap is smaller than that seen in the rest of the country.

Figure 6: Workplace Attendance and Essential Workers During the COVID-19 Pandemic (Dublin)



Source: Authors' calculations based on COVID-19 HPSC Detailed Statistics Profile, Google COVID-19 Community Mobility Reports, CSO POWSCAR 2016.

VII RESULTS IV – MULTIVARIATE ANALYSIS OF CASELOAD

Given the importance of mobility as an influence in the spread of COVID-19, we use regression modelling to examine the association between different types of mobility and COVID-19 cases. Six mobility variables are modelled using Google Community Mobility Reports location data: grocery and pharmacy; retail and recreation; parks; transit stations; workplaces; and residential.[14] Dummy variables to control for the imposition of the three national lockdowns are also included. The dataset covers the time from March 2020 to May 2021.

The dataset employed for this analysis is panel data, so a Hausman test is utilised to whether a fixed or random effects model should be used. The Hausman

[14] Although Google does not make the share of journeys by destination available, CSO National Travel Survey (CSO, 2021b) data provide some indication. In 2021, journeys by destination share were: work, 26 per cent; education, 1.2 per cent; shopping, eating or drinking, 32.1 per cent; visit family/friends/entertainment/leisure, 17.9 per cent; personal business/other, 5.8 per cent; companion/escort journey, 17 per cent. However, these shares are only for ages 25-34 with data for all age groups currently unavailable.

test returned a significant result at the 1 per cent significance level, indicating that a fixed effects model is appropriate in this case. As a result, time-invariant variables cannot be used as part of the model (Kohler and Kreuter, 2012).

Table 4: Multivariate Predictors of 14-day Incidence Rate – Fixed Effects Model

	Coef.	*Std. Err.*	*t*	*P>t*
Retail and Recreation	1.27	0.17	7.53	0.00
Grocery and Pharmacy	–1.33	0.17	–7.84	0.00
Parks	0.03	0.05	0.51	0.61
Transit Stations	0.37	0.13	2.88	0.00
Workplaces	2.86	0.23	12.59	0.00
Residential	10.15	0.69	14.70	0.00
Lockdown 1	–7.52	8.53	–0.88	0.38
Lockdown 2	26.87	6.01	4.47	0.00
Lockdown 3	90.53	6.16	14.68	0.00
Constant	34.41	6.73	5.11	0.00
R-squared	0.15			

Source: Authors' calculations based on COVID-19 HPSC Detailed Statistics Profile, Google COVID-19 Community Mobility Reports.

The results of the regression model are shown in Table 4. Of the mobility variables, an increased number of visits to retail and recreation locations, transit stations, workplaces and increased time spent in residential locations are associated with a higher 14-day incidence rate of COVID-19. A greater number of visits spent to grocery and pharmacy locations is associated with lower COVID-19 incidence while park visits are not significantly related to changes in the incidence rate. Lockdowns 2 and 3 were associated with significant increases in the incidence rate.

Of additional interest is spikes in the COVID-19 incidence rate witnessed in individual counties during the course of the pandemic. One hypothesised source of these spikes is gatherings following county GAA finals in the autumn of 2020.[15] To test this hypothesis, we examined the COVID-19 14-day incidence rate per 100k people in LEAs which contained teams that won the county final in either Gaelic football or hurling. The LEA was coded as a dummy variable and added as a regressor to the model shown in Table 4.[16] Therefore, the incidence rate in the county final LEAs is being compared to the rest of the LEAs in the county. The incidence rate for a six-week period following 30 GAA matches[17] (19 Gaelic football, ten hurling) was examined.

[15] Other relevant sources of spikes in individual counties include outbreaks in food processing plants and nursing homes. See Table A.8 in the accompanying Annex.
[16] The lockdown variables were omitted as they fell outside the period following most of the county finals.
[17] The Gaelic football championship in Cork was suspended until 2021 following the semi-final stage so the LEAs for the two victorious semi-final clubs were used.

Table 5: GAA Final Winners as Predictors of 14-day Incidence Rate

LEA	*Coef.*	*Std. Err.*	*t*	*P>t*
Ballymun-Finglas (Dublin)	164.77	30.57	5.39	0.000
Ballina (Mayo)	126.54	38.59	3.28	0.003
Edenderry (Offaly)	97.20	36.28	2.68	0.028
Monaghan (Monaghan)	81.37	34.47	2.36	0.033
Ratoath (Meath)	197.81	95.53	2.07	0.050

Source: Authors' calculations based on COVID-19 HPSC Detailed Statistics Profile.

Of the 30 GAA matches examined, statistically significant increases in the 14-day incidence rate following the match were found in the five LEAs shown in Table 5. The largest effect size was seen in Ballymun-Finglas where Ballymun Kickhams won the Dublin Gaelic football championship. The match was associated with a 165-case increase in the 14-day incidence rate per 100k people in the following six weeks versus the other LEAs in Dublin. Significant increases in the incidence rate following county finals were also seen in the LEAs of Ballina (Knockmore), Edenderry (Rhode), Monaghan (Scotstown) and Ratoath (Ratoath).

VIII DISCUSSION

As the COVID-19 pandemic continues to disrupt life around the world, this paper attempts to draw lessons from the Irish experience of dealing with the virus. Given the importance of personal contact in relation to the spread of the virus, we concentrate on the importance of mobility, especially the role of commuting, in the propagation of COVID-19. By comparing the incidence rate of the virus in counties with a commuting relationship with the incidence rate of neighbouring counties, we found a higher correlation between commuting counties. This suggests commuting may play a part in the spread of the virus. This is supported by the levels of workplace attendance during the pandemic.

As lockdown periods progressed, we found increasing levels of workplace attendance over and above what would be expected if only essential workers were physically going to work. This suggests increasing non-compliance with COVID-19 restrictions as lockdown periods continued. Additionally, lockdowns 2 and 3 in October 2020 and early 2021 respectively saw much quicker increases in workplace attendance after the imposition of the lockdown than was the case during the first lockdown in March 2020. Mobility-related variables were significantly associated with increased incidence of the virus at a national level, specifically visits to retail and recreation sites, transit stations, and workplaces. Additionally, individual events that may have encouraged social contacts such as GAA matches were associated with increases in the incidence rate in local areas.

The increasing levels of workplace attendance during the lockdown phases of the pandemic stress the importance of facilitating the ability to work from home as much as possible and providing adequate government assistance to those for whom working from home is not an option. Irish employees who cannot work from home are more likely to be less educated while, pre-COVID, those who worked from home were more likely to be full-time, over 30 years of age and in higher paid occupations (Crowley *et al*., 2021; Redmond and McGuinness, 2020b). To enable greater equality for remote working, government policy can enable more workers to operate from home through providing greater access to broadband, supporting stronger rights for flexible working, and outlining a clear framework for remote working that can be followed by employers and employees (Chung *et al*., 2020; Crowley and Doran, 2020). There may also be a need for governments to facilitate the transition of workers into jobs less susceptible to disruption by the virus through training and education programmes (Costa Dias *et al*., 2020).

The results also highlight the role of commuting in the dissemination of the virus, confirming analysis from other parts of the world such as United States (Dellicour *et al*., 2021; Kissler *et al*., 2020) and Italy (Di Porto *et al*., 2020). Although the movement of essential workers during lockdown periods was necessary to maintain essential services, the increased level of non-essential worker mobility as lockdowns progressed shows the difficulty of enforcing lockdown-type NPIs in the longer term.

The multivariate regression results reinforce the role of mobility and social contact in virus transmission. An increase in the number of visits to retail and recreation sites, transit stations and workplaces was associated with an increase in the incidence rate of COVID-19. The negative association between grocery and pharmacy visits is likely related to increased visits to those locations during lockdown periods, especially during lockdown 1. Increases in the incidence rate associated with increased time spent in residential settings is consistent with research showing household transmission as a key driver of COVID-19 transmission (Grijalva *et al*., 2020; Madewell *et al*., 2020).

The results also indicate a positive relationship between lockdown periods 2 and 3 and the COVID-19 incidence rate. Rather than showing the ineffectiveness of lockdowns, this result instead indicates the large number of cases that occurred in these periods relative to non-lockdown time periods. Lockdowns occur when cases are at their highest so a positive relationship between lockdown periods and cases is to be expected. The insignificant relationship between lockdown 1 and incidence rate may reflect the smaller overall number of confirmed cases in the first wave of the virus in Ireland, relative to the second and third waves.

The cause of higher per capita incidence rates in border counties relative to the rest of the country remains open to debate. Donegal is the only border county for which at least 5 per cent of commuters travel into Northern Ireland on a regular basis so cross-border commuting for the border counties is still not common.

However, LEAs in Donegal have the lowest correlation with LGDs in Northern Ireland in terms of incidence rate, which suggests cross-border contact did not influence COVID-19 transmission in Donegal.[18] It must be noted that commuting data only cover travel for work purposes in this instance so other forms of cross-border travel, such as for shopping or socialising, are not considered. Additionally, the level of NPIs implemented in both jurisdictions often diverged quite significantly over the course of the pandemic. The finding that incidence rates in Irish LEAs were more positively associated with Northern Irish LGDs with a one-week lag than concurrent incidence rates may suggest that changes in infection rates in border counties are precipitated by changes in Northern Irish rates, but establishing such a causal pattern is beyond the scope of this paper.

REFERENCES

Arnon, A., J. Ricco and K. Smetters, 2020. *Epidemiological and economic effects of lockdown* (BPEA Conference Drafts, September 24, 2020). Washington D.C.: Brookings Institution.

Boudou, M., C. Ó hAiseadha, P. Garvey, J. O'Dwyer and P. Hynds, 2021. "Breakpoint modelling of temporal associations between non-pharmaceutical interventions and symptomatic COVID-19 incidence in the Republic of Ireland", *PloS One*, *16*(7), e0255254.

Bryant, P. and A. Elofsson, 2020. "Estimating the impact of mobility patterns on COVID-19 infection rates in 11 European countries", *PeerJ*, *8*, e9879.

Byrne, S., D. Coates, E. Keenan and T. McIndoe-Calder, 2020. *The initial labour market impact of COVID-19* (No. 0/EL/20). Dublin: Central Bank of Ireland.

Carroll, R., 2020, April 29. "Concerns raised as Covid-19 cases surge along Irish border", *The Guardian.* https://www.theguardian.com/world/2020/apr/29/concerns-raised-as-covid-19-cases-surge-along-irish-border.

Central Statistics Office, 2020. *Quarterly national accounts quarter 3 2020.* Dublin: CSO.

Central Statistics Office, 2021a. *Quarterly national accounts quarter 4 2020.* Dublin: CSO.

Central Statistics Office, 2021b. *National travel survey.* Dublin: CSO.

Charoenwong, B., A. Kwan and V. Pursiainen, 2020. "Social connections with COVID-19–affected areas increase compliance with mobility restrictions", *Science Advances*, *6*(47), eabc3054.

Chung, H., H. Seo, S. Forbes and H. Birkett, 2020. *Working from home during the COVID-19 lockdown: Changing preferences and the future of work*. Birmingham: University of Birmingham. https://www.birmingham.ac.uk/Documents/college-social-sciences/business/research/wirc/epp-working-from-home-COVID-19-lockdown.pdf.

Costa Dias, M., R. Joyce, F. Postel-Vinay and X. Xu, 2020. "The challenges for labour market policy during the Covid-19 pandemic", *Fiscal Studies*, *41*(2), 371-382.

Crowley, F. and J. Doran, 2020. "COVID-19, occupational social distancing and remote working potential: An occupation, sector and regional perspective", *Regional Science Policy & Practice*, *12*(6), 1211-1234.

Crowley, F., J. Doran and G. Ryan, 2021. COVID-19: "How important is education for social distancing and remote work", *The Economic and Social Review*, *52*(2, Summer), 217-239.

[18] There have been media reports of significant non-compliance with government restrictions in border counties, especially Donegal (see Carroll, 2020; McCurry, 2021; O'Loughlin *et al*., 2020), but this evidence remains anecdotal for now.

Dellicour, S., S.L. Hong, B. Vrancken, A. Chaillon, M.S. Gill, M.T. Maurano, S. Ramaswami, P. Zappile, C. Marier, G.W. Harkins, G. Baele, R. Duerr and A. Heguy, 2021. "Dispersal dynamics of SARS-CoV-2 lineages during the first epidemic wave in New York City", *PLoS pathogens*, *17*(5), e1009571.

Department of Finance, 2020. *Stability programme update 2020 incorporating the department of finance's spring forecasts (April 2020)*. Dublin: Department of Finance.

Department of Finance, 2021. *Emerging economic developments – real-time economic domestic indicators* (14 April 2021). Dublin: Department of Finance.

Di Porto, E., P. Naticchioni and V. Scrutinio, 2020. *Partial lockdown and the spread of COVID-19: Lessons from the Italian case* (No. 13375). Bonn: Institute of Labor Economics (IZA).

Grannell, J.J. and J.R. Grannell, 2020. *A two-region SEIR COVID-19 epidemic model for the island of Ireland*. MedRxiv. https://doi.org/10.1101/2020.10.31.20223727.

Grijalva, C.G., M.A. Rolfes, Y. Zhu, H.Q. McLean, K.E. Hanson, E.A. Belongia, N.B. Halasa, A. Kim, C. Reed, A.M. Fry and H.K. Talbot, 2020. "Transmission of SARS-COV-2 infections in households—Tennessee and Wisconsin, April–September 2020", *Morbidity and Mortality Weekly Report*, *69*(44), 1631-1634.

Health Information and Quality Authority, 2020. *The impact of Covid-19 on nursing homes in Ireland* (July 2020). Cork: HIQA.

Kennelly, B., M. O'Callaghan, C. Coughlan, J. Cullinan, E. Doherty, L. Glynn, E. Moloney and M. Queally, 2020. "The COVID-19 pandemic in Ireland: An overview of the health service and economic policy response", *Health Policy and Technology*, *9*(4), 419-429.

Kissler, S.M., N. Kishore, M. Prabhu, D. Goffman, Y. Beilin, R. Landau, C. Gyamfi-Bannerman, B.T. Bateman, J. Snyder, A.S. Razavi, D. Katz, J. Gal, A. Bianco, J. Stone, D. Larremore, C.O. Buckee and Y.H. Grad, 2020. "Reductions in commuting mobility correlate with geographic differences in SARS-CoV-2 prevalence in New York City", *Nature Communications*, *11*(1), 1-6.

Kohler, U. and F. Kreuter, 2012. *Data analysis using Stata* (3rd ed.). College Station, TX: Stata Press.

Madewell, Z.J., Y. Yang, I.M. Longini, M.E. Halloran and N.E. Dean, 2020. "Household transmission of SARS-CoV-2: A systematic review and meta-analysis", *JAMA Network Open*, *3*(12), e2031756-e2031756.

McAloon, C.G., P. Wall, F. Butler, M. Codd, E. Gormley, C. Walsh, J. Duggan, T.B. Murphy, P. Nolan, B. Smyth and K. O'Brien, 2021. *Numbers of close contacts of individuals infected with SARS-CoV-2 and their association with government intervention strategies.* MedRxiv. https://doi.org/10.1101/2021.01.20.21250109.

McCurry, C., 2021, May 2. "Border counties warned of worrying coronavirus case numbers", *Irish Examiner*. https://www.irishexaminer.com/news/arid-40279265.html.

O'Donoghue, C., D.M. Sologon, I. Kyzyma and J. McHale, 2020. "Modelling the distributional impact of the COVID-19 crisis", *Fiscal Studies*, *41*(2), 321-336.

O'Loughlin, C., P. Ryan and E. O'Regan, 2019, October 12. "Cavan headed for Covid-19 danger zone as Border counties may face Level 4 restrictions", *Irish Independent*. https://www.independent.ie/irish-news/cavan-headed-for-covid-19-danger-zone-as-border-counties-may-face-level-4-restrictions-39613106.html.

O'Toole, C., 2020. *The lockdown tale of two economies in Ireland: How big tech and pharma bucked the trend* (Research Note 2020/03/01). Dublin: ESRI.

Rahman, M., J.C. Thill and K.C. Paul, 2020. "COVID-19 pandemic severity, lockdown regimes, and people's mobility: Early evidence from 88 countries", *Sustainability*, *12*(21), 9101.

Redmond, P. and S. McGuinness, 2020a. *Essential employees during the Covid-19 crisis* (ESRI Survey and Statistical Report Series Number 85). Dublin: ESRI.

Redmond, P. and S. McGuinness, 2020b. *Who can work from home in Ireland?* (ESRI Survey and Statistical Report Series Number 87). Dublin: ESRI.

Shearston, J.A., M.E. Martinez, Y. Nunez and M. Hilpert, 2021. "Social-distancing fatigue: evidence from real-time crowd-sourced traffic data", *Science of The Total Environment*, *792*, 148336.

ANNEX: ASSESSING THE IMPACT OF MOBILITY ON COVID-19: SPATIAL AND ECONOMIC EVIDENCE FROM IRELAND

Table A.1: List of Key Non-pharmaceutical Interventions Introduced in Ireland in Response to the COVID-19 Pandemic

Date	*Intervention*	*Restriction Increase/Decrease*
29/2/20	First case of COVID-19 confirmed in Ireland	
9/3/20	Annual St. Patrick's Day parades cancelled throughout Ireland	Increase
12/3/21	Mandatory closures of schools, colleges, childcare facilities and state-run cultural institutions. Indoor gatherings of more than 100 people and outdoor gatherings of more than 500 people banned. People encouraged to work from home.	Increase
15/3/21	Pubs closed	Increase
24/3/21	Closure of non-essential businesses. All indoor and outdoor sporting activities cancelled. Essential services required to implement physical distancing. Citizens not permitted to take unnecessary travel. Citizens required to work from home unless they worked in essential services.	Increase
27/3/21	Stay at home measures announced for all but essential workers. Movement within 2km of home allowed for exercise. No gatherings with anyone outside household. People aged over 70 or medically vulnerable advised not to leave own home.	Increase
8/4/20	An Garda Síochána given additional powers including arrest without warrant to enforce pandemic restrictions.	Increase
1/5/20	Roadmap to easing restrictions in Ireland that includes five stages announced by the government.	
18/5/20	Phase 1 of reopening economy and society Outdoor work is allowed to resume and shops that cater for mainly outdoor work are allowed to open. Groups of up to four people are allowed to meet outdoors within 5 km of home. Outdoor public amenities, sport and fitness activities are allowed to open.	Decrease

Table A.1: List of Key Non-pharmaceutical Interventions Introduced in Ireland in Response to the COVID-19 Pandemic (Contd.)

Date	*Intervention*	*Restriction Increase/Decrease*
8/6/20	Phase 2 of reopening economy and society Travel within a county or up to 20km from home if crossing county borders is allowed. Groups of up to six people are allowed to meet either outdoors or indoors. Organised sporting, cultural or social activities for up to 15 people are allowed. Funerals with up to 25 people in attendance are allowed.	Decrease
25/6/20	Phase 3 of reopening economy and society All domestic travel restrictions lifted. Cafes, restaurants, hotels, hostels, galleries, museums and pubs that serve food are allowed to open. Higher risk retail outlets such as hairdressers are allowed to open. Indoor leisure facilities can reopen, festivals and cultural activities can reopen. Indoor gatherings of up to 50 people and outdoor gatherings of up to 200 people allowed if public health advice is followed.	Decrease
7/8/20	Local lockdowns in Kildare, Laois and Offaly. Residents of the three counties not permitted to travel outside of their counties except for in limited circumstances including to travel to and from work. Local restaurants, cafés, pubs serving food, cinemas, gyms, theatres, museums, galleries, bingo halls, casinos, betting shops, leisure centres and other indoor recreational and cultural outlets closed. All local indoor gatherings restricted to six people and outdoor gatherings restricted to 15 people.	Increase
18/8/20	Outdoor events limited to 15 people. Indoor events limited to six people except for weddings and funerals. Gardaí given new powers to enforce rules around social gatherings in restaurants and bars serving food, and in private homes. Sports events and matches revert to behind closed doors with strict avoidance of social gatherings before and after events.	Increase

Table A.1: List of Key Non-pharmaceutical Interventions Introduced in Ireland in Response to the COVID-19 Pandemic (Contd.)

Date	*Intervention*	*Restriction Increase/Decrease*
21/8/20	Lockdown COVID-19 restrictions lifted in Laois and Offaly. Restrictions lifted in Kildare ten days later.	Decrease
1/9/20	Primary and secondary schools reopen.	Decrease
18/9/20	Level 3 restrictions introduced in Dublin. All indoor museums, galleries, cinemas and other cultural attractions close. Visitors are allowed from one other household only. No organised indoor gatherings to take place. Organised outdoor gatherings up to only 15 people are permitted. People living in Dublin should remain in the county other than for essential purposes. People living outside of Dublin should not travel to Dublin.	Increase
21/9/20	'Wet' pubs that do not serve food reopen outside Dublin.	Decrease
7/10/20	Level 3 restrictions introduced for entire country. Visits to private homes limited to six people from two different households. Social family gatherings are suspended. Organised indoor gatherings are suspended while outdoor gatherings are limited to 15 people. Residents must remain in their counties of residence unless traveling for work, education, or other essential purposes. Restaurants and cafes allowed to remain open for takeaway and delivery.	Increase
21/10/20	Level 5 restrictions introduced for entire country. 5km containment radius introduced. Schools, early learning and childcare services remain open and are deemed essential. Visits to other people's homes or gardens banned. Non-essential businesses and services to close.	Increase
1/12/20	Non-essential retail, hairdressers, gyms, leisure centres, museums, galleries, libraries, cinemas and places of worship reopen. People advised to stay within their county apart from work, education and other essential purposes.	Decrease

Table A.1: List of Key Non-pharmaceutical Interventions Introduced in Ireland in Response to the COVID-19 Pandemic (Contd.)

Date	*Intervention*	*Restriction Increase/Decrease*
4/12/20	Restaurants, pubs serving food and hotel restaurants reopen for indoor dining with additional restrictions.	Decrease
18/12/20	Households can mix with up to two other households. Travel outside your county permitted.	Decrease
24/12/20	Level 5 lockdown restrictions introduced. Restaurants and gastro-pubs must close at 3pm on 24 December. Hotels may provide food and bar services to guests only after 3pm on Christmas Eve. Hotels may only open to guests for essential purposes after 26 December. Up until 26 December, visits from up to two other households will be permitted. Household visits will be reduced to one other household from 27 December. From 1 January, no household mixing will be allowed except for compassionate, care or childcare reasons. No new inter-county travel will be allowed after 26 December. Personal services, including hairdressers and barbers must close.	Increase
31/12/20	All schools to remain closed after the Christmas break. All non-essential retail and services closed. People must stay at home except for work, education or other essential purposes, and will be allowed to exercise within 5km of home.	Increase
11/2/21	Special education schools reopen.	Decrease
1/3/21	Some primary and secondary school students return to classroom.	Decrease
26/3/21	Mandatory hotel quarantine system for all passengers arriving in the country from high-risk countries introduced.	Increase
12/4/21	5km travel limit lifted, people can travel within county or up to 20km from their home if they are crossing county boundaries. Resumption of all residential construction work. Two households can meet up outdoors. Full reopening of all schools.	Decrease

Table A.1: List of Key Non-pharmaceutical Interventions Introduced in Ireland in Response to the COVID-19 Pandemic (Contd.)

Date	*Intervention*	*Restriction Increase/Decrease*
26/4/21	Outdoor sports facilities (such as pitches, golf courses and tennis courts) reopen. Outdoor visitor attractions (such as zoos, open pet farms, heritage sites) reopen. Maximum attendance at funerals would increase from ten to 25 on compassionate grounds.	Decrease
10/5/21	All hairdressers, barbers, beauticians, galleries, museums, libraries and other cultural attractions allowed to reopen. Resumption of non-essential retail on a phased basis. Resumption of inter-county travel. In-person religious services resume. Three households (or six people) from individual households allowed to meet outdoors.	Decrease

Source: Department of Health.

Table A.2: Essential Sectors During Lockdown 1 of COVID-19 Pandemic in Ireland

Industry	*Services*
Agriculture and fishing	Farmers, farm labourers, farm relief service workers, and others involved directly or indirectly in crop and animal production and related activities (including veterinary services), and workers involved in fishing
Manufacturing	The manufacture of food and beverage products; prepared animal feeds; work-wear apparel or footwear; pulp, paper and paperboard; wood; printing and reproduction of newspapers and other media services; coke and refined petroleum products; alumina; chemicals and chemical products; pharmaceutical products and pharmaceutical preparations; products necessary for the supply chain of essential services; computer, electronic and optical products including semi-conductors; electrical equipment, machinery and other equipment (including agricultural and forestry machinery); medical devices; and medical and dental equipment and supplies
Repair and installation of machinery and equipment	The supply, repair and installation of machinery and equipment; industrial machinery and equipment for essential services
Electricity, gas and water	Electric power generation, transmission and distribution; extraction and distribution of gas; water collection, treatment and supply; sewerage; waste collection, remediation activities and other waste management treatment and disposal activities
Construction	Essential health and related projects relevant to the COVID-19 crisis, and supplies necessary for such projects; repair/construction of critical road and utility infrastructure; delivery of emergency services to businesses and homes on an emergency call out basis in areas such as electrical, plumbing, glazing and roofing
Wholesale and retail sale	Retail services in accordance with the separate "Updated Essential Retail Outlets 2" list; wholesale and distribution services necessary for the sale of food, beverages, fuel, medicines, medical products and devices and essential household products; takeaways and food delivery services
Transport storage and communication	Land transport (e.g. bus, rail and taxi services); road, rail, sea and air freight; sea and air passenger services; ports and airports; warehousing and support activities for transportation including cargo handling; postal and courier activities; network control and critical maintenance (including roads); and safety related functions

Table A.2: Essential Sectors During Lockdown 1 of COVID-19 Pandemic in Ireland (Contd.)

Industry	*Services*
Accommodation and food services	Hotels or similar providing essential accommodation (including homeless, direct provision and related services); food and beverage service activities in accordance with the separate "Updated Essential Retail Outlets 3" list or for supply to a business engaged in an essential service
Information and communications	Publishing of newspapers, journals and periodicals; video, television programme production, sound recording, radio and television broadcasting; wired and satellite and telecommunications activities; internet and cloud providers; data centres and related services
Financial and legal activities	Banking and financial services (including banks, credit unions and post offices); accountancy, legal and insurance services, necessary to support essential services and vulnerable people
Professional, scientific and technical activities	Engineering, technical testing activities and analysis, scientific research and development activities, regulation, inspection and certification services, necessary to support essential services
Rental and leasing activities	Rental and lease of cars, light motor vehicles and trucks, necessary to support the provision of essential services
Administrative and support activities	Where necessary to support other essential services: employment placement and human resources associated with the recruitment and deployment of workers; security activities to assist in the delivery of essential services and the securing of premises closed to the public; cleaning of buildings and industrial cleaning activities; business support activities which are necessary to support essential services included on this list; payroll and payment services necessary for the operation of businesses; data processing, hosting and related activities
Public administration and defence	Public administration activities necessary to support essential services and provision of social protection benefits (including Civil Service and Local Government); An Garda Síochána, Garda Staff and the Garda Reserve; public order, safety, fire service and ambulance activities; the Defence Forces; emergency call answering service; to ensure administration of justice; Prison services and Child Dentation services; cyber-security; regulatory processes and certification required to ensure supply chains, food, medicine and general process safety; operation of botanical gardens, parks, forests and nature reserves; funeral services; religious personnel; office-holders and public representatives

Table A.2: Essential Sectors During Lockdown 1 of COVID-19 Pandemic in Ireland (Contd.)

Industry	*Services*
Human health and social work activities	Hospital services; paramedical and essential therapy activities; public health activities (including all those deployed to contract tracing and COVID-19 testing services); laboratory services; drug treatment and addiction services; hospice services; pharmacy services; primary care, general and specialist medical practice activities provided by public and private providers; emergency dental practice activities; blood donation service; residential care activities (including nursing care, mental health and substance abuse, elderly and persons with disabilities, children's residential services); homecare, home help and other community services; social work and social care activities (including disability services, mental health, child protection and welfare, domestic, sexual and gender based violence, homeless services including outreach); ambulance/pre-hospital emergency care services; minor injury units; maternity services; health, social work, environmental, food safety regulatory activities; non-centre based childcare for those providing essential services
Community and voluntary services	Community and voluntary workers, working in a publicly commissioned service, not otherwise included on the list, deployed to assist in the delivery of essential services; volunteer services operating under the local authority emergency management framework in accordance with public health guidance

Source: Government of Ireland.

Table A.3: Essential Sectors During Lockdown 2 of COVID-19 Pandemic in Ireland

Industry	*Services*
Agriculture and fishing	Farmers, farm labourers, farm relief service workers, and others involved directly or indirectly in crop and animal production and related activities (including veterinary services), and workers involved in fishing; acquaculture and fish farming; horticulture; forestry; marts held online only
Manufacturing	The manufacture of food and beverage products; prepared animal feeds; work-wear apparel, personal protective equipment or footwear; pulp, paper and paperboard; wood; printing and reproduction of newspapers and other media services; coke and refined petroleum products; alumina; chemicals and chemical products; pharmaceutical products and pharmaceutical preparations; products necessary for the supply chain of essential services; the manufacture of products necessary for national and international supply chains, other than such supply chains referred to for essential services; computer, electronic and optical products including semi-conductors; electrical equipment, machinery and other equipment (including agricultural and forestry machinery); medical devices; and medical and dental equipment and supplies
Repair and installation of machinery and equipment	The supply, repair and installation of machinery and equipment; industrial machinery and equipment for essential services; the repair of mechanically propelled vehicles or the repair of bicycles and related facilities
Electricity, gas and water	Electric power generation, transmission and distribution; extraction and distribution of gas and decommissioning activities related to offshore gas field facilities; water collection, treatment and supply; sewerage; waste collection, remediation activities and other waste management treatment and disposal activities
Construction	Construction or development work and the provision of support services relating to construction and development work; the repair, maintenance and construction of road, rail and utility infrastructure; the supply and delivery of maintenance and repair services to businesses and places of residence (including electrical, gas, plumbing, glazing and roofing services)
Wholesale and retail sale	Retail services in accordance with the separate "Updated Essential Retail Outlets 2" list; wholesale and distribution services necessary for the sale of food, beverages, fuel, medicines, medical products and devices, essential items for

Table A.3: Essential Sectors During Lockdown 2 of COVID-19 Pandemic in Ireland (Contd.)

Industry	*Services*
Wholesale and retail sale (Contd.)	the health and welfare of animals, or supplies for the essential upkeep and functioning of a place of residence and essential household products; takeaways and food delivery services; the operation of automated teller machines and related services.
Transport storage and communication	Land transport (e.g. bus, rail and taxi services); road, rail, sea and air freight; sea and air passenger services; ports and airports; warehousing and support activities for transportation including cargo handling; postal and courier activities; network control and critical maintenance (including roads); and safety related functions
Accommodation and food services	Hotel or similar accommodation services to persons who are guests of those hotels or similar accommodation on the 21st day of October 2020 until the date of their departure; hotel or similar accommodation services to guests travelling for purposes other than social, recreational, cultural or tourist purposes; hotels or similar providing essential accommodation (including homeless, direct provision and related services); food and beverage service activities in accordance with the separate "Updated Essential Retail Outlets 3" list or for supply to a business engaged in an essential service; the provision of food or beverage takeaway or delivery services
Information and communications	Publishing of newspapers, journals and periodicals; video, television programme production, sound recording, radio and television broadcasting; wired and satellite and telecommunications activities; internet and cloud providers; data centres and related services
Financial and legal activities	Banking and financial services (including banks, credit unions and post offices); accountancy, legal and insurance services (no longer just for essential services/vulnerable people)
Professional, scientific and technical activities	Engineering, technical testing activities and analysis; scientific research and development activities; regulation, inspection and certification services (no longer just for essential services)
Rental and leasing activities	Rental and lease of bicycles, cars, light motor vehicles and trucks (no longer just for essential services)
Administrative and support activities	(No longer just for essential services unless stated) employment placement and human resources associated with the recruitment and deployment of workers; data processing, hosting and related activities; funeral burial and related services; payroll and payment services necessary for the operation of businesses;

Table A.3: Essential Sectors During Lockdown 2 of COVID-19 Pandemic in Ireland (Contd.)

Industry	*Services*
Administrative and support activities (Contd.)	security activities to assist in the delivery of essential services and the securing of premises closed to the public; cleaning of buildings and industrial cleaning activities necessary to support essential services; business support activities (IT and communications technology support and sales, repair and maintenance) which are necessary to support essential services, a person working from their place of residence where the business concerned is being operated from a place of residence or a business that is not an essential service, to the extent required to maintain that business in operation or to minimise any delay in the business resuming operation after these Regulations have ceased to be in operation; essential health and safety training (that cannot be done remotely)
Public administration and defence	An Garda Síochána, Garda Staff and the Garda Reserve; public order, safety, fire service and ambulance activities; the Defence Forces; emergency call answering service; services to ensure administration of justice; Prison services and Child Dentation services; cybersecurity; regulatory processes and certification required to ensure supply chains, food, medicine and general process safety; operation of botanical gardens, parks, forests, nature reserves and playgrounds; funeral services; religious personnel; office-holders and public representatives; security, care and maintenance of premises, collections and objects under the care and management of the National Cultural Institutions; services provided under the Child Care Act 1991; adoption services under the Adoption Act 2010; services provided to victims; services, including regulation services, provided by, and activities of, the Central Bank of Ireland, the Investor Compensation Company DAC (otherwise known as the Investor Compensation Company Limited) and the National Treasury Management Agency; any other service provided, or function performed, by a public body where the provision of the service or performance of the function is necessary to support or manage other essential services or the response of the State to the spread of COVID-19; Driver Testing Services provided by the Road Safety Authority for people involved in the provision of essential services or essential retail outlets; Driving instruction provided by instructors on the Register of Approved Driving instructors where the person receiving instruction has a booking reserved to undergo a test; NCT for those with existing appointments; specific statutory planning

Table A.3: Essential Sectors During Lockdown 2 of COVID-19 Pandemic in Ireland (Contd.)

Industry	*Services*
	system activities, to the extent that they cannot be carried out remotely.
Human health and social work activities	Hospital services; therapy services provided by a member of a designated profession (no longer just essential); services relating to public health, including services relating to the identification, tracing and contacting of persons who have been in contact with persons who have been diagnosed, or are suspected of having been infected, with COVID-19, and the testing of persons for COVID-19; laboratory services; drug treatment and addiction services; hospice services; pharmacy services; primary care and general and specialist medical practice activities; dental services (no longer just emergency); blood donation and related services; tissue or organ donation and related services; residential care services (including nursing care, mental health and substance abuse services, services for elderly persons and persons with disabilities) and children's residential services; homecare, home help and other health services in the community; social work and social care services, (including disability services, mental health services, child protection and welfare services, domestic, sexual and gender-based violence services) and homeless services including homeless outreach services; paramedical, ambulance and pre-hospital care services; services provided by minor injury units; maternity services; health and social work services; food safety and environmental services; regulated childcare services and the care of children for persons providing essential services
Education	Primary and post primary school; higher and further education, insofar as onsite presence is required, and such education activities cannot be held remotely
Community and voluntary services	Services not otherwise specified in this Schedule, provided by community and voluntary workers and the Civil Defence, as part of a publicly commissioned service, deployed to assist in the delivery of essential services; volunteer services operating under the local authority emergency management framework in accordance with public health guidance
Diplomatic missions and consular affairs	The provision of services essential to the functioning of diplomatic missions and consular posts in the State

Source: Government of Ireland.

Table A.4: Essential Sectors During Lockdown 3 of COVID-19 Pandemic in Ireland

Industry	*Services*
Agriculture and fishing	Farmers, farm labourers, farm relief service workers, and others involved directly or indirectly in crop and animal production and related activities (including veterinary services), and workers involved in fishing; acquaculture and fish farming; horticulture; forestry; marts held online only
Manufacturing	The manufacture of food and beverage products; prepared animal feeds; work-wear apparel, personal protective equipment or footwear; pulp, paper and paperboard; wood; printing and reproduction of newspapers and other media services; coke and refined petroleum products; alumina; chemicals and chemical products; pharmaceutical products and pharmaceutical preparations; products necessary for the supply chain of essential services; the manufacture of products necessary for national and international supply chains, other than such supply chains referred to for essential services; computer, electronic and optical products including semi-conductors; electrical equipment, machinery and other equipment (including agricultural and forestry machinery); medical devices; and medical and dental equipment and supplies
Repair and installation of machinery and equipment	The supply, repair and installation of machinery and equipment; industrial machinery and equipment for essential services; the repair of mechanically propelled vehicles or the repair of bicycles and related facilities
Electricity, gas and water	Electric power generation, transmission and distribution; extraction and distribution of gas and decommissioning activities related to offshore gas field facilities; water collection, treatment and supply; sewerage; waste collection, remediation activities and other waste management treatment and disposal activities
Construction	Construction will close from 6pm on Friday 8 January, with limited exceptions including: essential health and related projects including those relevant to preventing, limiting, minimising or slowing the spread of COVID-19; social housing projects, including voids, designated as essential sites by Local Authorities based on set criteria; housing adaptation grants where the homeowner is agreeable to adaptions being undertaken in their home; repair, maintenance and construction of critical transport and utility infrastructure; education facilities sites designated as essential by Department of

Table A.4: Essential Sectors During Lockdown 3 of COVID-19 Pandemic in Ireland (Contd.)

Industry	*Services*
Construction (Contd.)	Education; supply and delivery of essential or emergency maintenance and repair services to businesses and places of residence (including electrical, gas, oil, plumbing, glazing and roofing services) on an emergency call-out basis; certain large construction projects in the exporting / FDI sector based on set criteria; private homes that are practically complete and scheduled for habitation by 31 January 2021
Wholesale and retail sale	Retail services in accordance with the separate "Updated Essential Retail Outlets2 " list; wholesale and distribution services necessary for the sale of food, beverages, fuel, medicines, medical products and devices, essential items for the health and welfare of animals, or supplies for the essential upkeep and functioning of a place of residence and essential household products; takeaways and food delivery services; the operation of automated teller machines and related services
Transport storage and communication	Land transport (e.g. bus, rail and taxi services); road, rail, sea and air freight; sea and air passenger services; ports and airports; warehousing and support activities for transportation including cargo handling; postal and courier activities; network control and critical maintenance (including roads); and safety related functions
Accommodation and food services	Hotel or similar accommodation services to guests travelling for purposes other than social, recreational, cultural or tourist purposes; hotels or similar providing essential accommodation (including homeless, direct provision and related services); hotel or similar accommodation services to guests attending a wedding; food and beverage service activities in accordance with the separate "Updated Essential Retail Outlets3 " list or for supply to a business engaged in an essential service; the provision of food or beverage takeaway or delivery services
Information and communications	Publishing of newspapers, journals and periodicals; video, television programme production, sound recording, radio and television broadcasting; wired and satellite and telecommunications activities; internet and cloud providers; data centres and related services
Financial and legal activities	Banking and financial services (including banks, credit unions and post offices); accountancy, legal and insurance services
Professional, scientific and technical activities	Engineering, technical testing activities and analysis; scientific research and development activities; regulation, inspection and certification services

Table A.4: Essential Sectors During Lockdown 3 of COVID-19 Pandemic in Ireland (Contd.)

Industry	*Services*
Rental and leasing activities	Property services, property letting and management services; rental and lease of bicycles, cars, light motor vehicles and trucks
Administrative and support activities	Employment placement and human resources associated with the recruitment and deployment of workers engaged in the provision of essential workers; data processing, hosting and related activities; funeral burial and related services; payroll and payment services necessary for the operation of businesses; security activities to assist in the delivery of essential services and the securing of premises closed to the public; cleaning of buildings and industrial cleaning activities necessary to support essential services; business support activities (IT and communications technology support and sales, repair and maintenance) which are necessary to support essential services, a person working from their place of residence where the business concerned is being operated from a place of residence or a business that is not an essential service, to the extent required to maintain that business in operation or to minimise any delay in the business resuming operation after these Regulations have ceased to be in operation; essential health and safety training (that cannot be done remotely)
Public administration and defence	An Garda Síochána, Garda Staff and the Garda Reserve; public order, safety, fire service and ambulance activities; the Defence Forces; emergency call answering service; services to ensure administration of justice; Prison services and Child Dentation services; cybersecurity; regulatory processes and certification required to ensure supply chains, food, medicine and general process safety; operation of botanical gardens, parks, forests, nature reserves and playgrounds; funeral services; religious personnel; office-holders and public representatives; security, care and maintenance of premises, collections and objects under the care and management of the National Cultural Institutions; services provided under the Child Care Act 1991; adoption services under the Adoption Act 2010; services provided to victims; services, including regulation services, provided by, and activities of, the Central Bank of Ireland, the Investor Compensation Company DAC (otherwise known as the Investor Compensation Company Limited) and the National Treasury Management Agency; any other service provided, or function performed, by a public body where the provision of

Table A.4: Essential Sectors During Lockdown 3 of COVID-19 Pandemic in Ireland (Contd.)

Industry	*Services*
Public administration and defence	the service or performance of the function is necessary to support or manage other essential services or the response of the State to the spread of COVID-19; Driver Testing Services provided by the Road Safety Authority for people involved in the provision of essential services or essential retail outlets; Driving instruction provided by instructors on the Register of Approved Driving instructors where the person receiving instruction has a booking reserved to undergo a test; Commercial Vehicle Roadworthiness Test services provided by the Road Safety Authority; NCT for those with existing appointments; specific statutory planning system activities, to the extent that they cannot be carried out remotely; National Driver Licence Service, insofar as it provides services by appointment to persons involved in the provision of essential services or essential retail outlets, and insofar as such services cannot be carried out remotely
Human health and social work activities	Hospital services; therapy services provided by a member of a designated profession; services relating to public health, including services relating to the identification, tracing and contacting of persons who have been in contact with persons who have been diagnosed, or are suspected of having been infected, with COVID-19, and the testing of persons for COVID-19; laboratory services; drug treatment and addiction services; hospice services; pharmacy services; primary care and general and specialist medical practice activities; dental services; blood donation and related services; tissue or organ donation and related services; residential care services (including nursing care, mental health and substance abuse services, services for elderly persons and persons with disabilities) and children's residential services; homecare, home help and other health services in the community; social work and social care services, (including disability services, mental health services, child protection and welfare services, domestic, sexual and gender-based violence services) and homeless services including homeless outreach services; paramedical, ambulance and pre-hospital care services; services provided by minor injury units; maternity services; food safety and environmental services; regulated childcare services and the care of children for persons providing essential services and vulnerable children; youth work services that cannot be provided remotely; anti-doping services

Table A.4: Essential Sectors During Lockdown 3 of COVID-19 Pandemic in Ireland (Contd.)

Industry	*Services*
Education	Certain education provision such as teaching, SNA support and other services required to support the delivery of the education related services being provided under Level 5.
Community and voluntary services	Services not otherwise specified in this Schedule, provided by community and voluntary workers and the Civil Defence, as part of a publicly commissioned service, deployed to assist in the delivery of essential services; volunteer services operating under the local authority emergency management framework in accordance with public health guidance.
Diplomatic missions and consular affairs	The provision of services essential to the functioning of diplomatic missions and consular posts in the State.

Source: Government of Ireland.

Table A.5: Essential Retail Outlets During Lockdown 1 of COVID-19 Pandemic in Ireland

Retail Outlet
1. Retail and wholesale sale of food, beverages and newspapers in non-specialised and specialised stores
2. Retail sale of household consumer products necessary to maintain the safety and sanitation of residences and businesses
3. Pharmacies/chemists and retailers providing pharmaceuticals, pharmaceutical or dispensing services
4. Retail sale of selling medical and orthopaedic goods in specialised stores
5. Fuel stations and heating fuel providers
6. Retail sale of essential items for the health and welfare of animals, including animal feed and medicines, animal food, pet food and animal supplies including bedding
7. Laundries and drycleaners
8. Banks, post offices and credit unions
9. Retail sale of safety supply stores (work clothes, Personal Protective Equipment, for example)

Source: Government of Ireland.

Table A.6: Essential Retail Outlets During Lockdown 2 of COVID-19 Pandemic in Ireland

Retail Outlet
1. Outlets selling food or beverages on a takeaway basis, or newspapers, whether on a retail or wholesale basis and whether in a non-specialised or specialised outlet
2. Markets that, wholly or principally, offer food for sale
3. Outlets selling products necessary for the essential upkeep and functioning of places of residence and businesses, whether on a retail or wholesale basis
4. Pharmacies, chemists and retailers or wholesalers providing pharmaceuticals or pharmaceutical or dispensing services, whether on a retail or wholesale basis
5. Outlets selling health, medical or orthopaedic goods in a specialised outlet, whether on a retail or wholesale basis
6. Fuel service stations and heating fuel providers
7. Outlets selling essential items for the health and welfare of animals (including animal feed and veterinary medicinal products, pet food, animal bedding and animal supplies), whether on a retail or wholesale basis
8. Laundries and drycleaners
9. Banks, post offices and credit unions
10. Outlets selling safety supplies (including work-wear apparel, footwear and personal protective equipment), whether on a retail or wholesale basis
11. Hardware outlets, builders' merchants and outlets that provide, whether on a retail or wholesale basis: hardware products necessary for home and business maintenance or construction and development, sanitation and farm equipment, supplies and tools essential for farming or agriculture purposes
12. Outlets providing for the repair and maintenance of mechanically propelled vehicles or bicycles and any related facilities (including tyre sales and repairs)
13. The following outlets, insofar as they offer services on an emergency basis only: outlets providing hearing test services or selling hearing aids and appliances; outlets selling office products and services for businesses or for relevant persons working from their respective places of residence, whether on a retail or wholesale basis; outlets providing electrical, information and communications technology and telephone sales, repair and maintenance services for places of residence and businesses
14. Any other retail outlet that operates an online or other remote system of ordering goods for purposes of collection at the retail outlet
15. Outlets selling food or beverages whether on a retail or wholesale basis and whether in a non-specialised or specialised outlet: insofar as they sell food or beverages on a takeaway basis or for consumption off the premises; insofar as they are staff canteens operating for the exclusive use of persons working in, or at, a particular premises; or hotels or similar accommodation services insofar as they sell food or beverages for consumption on the premises
16. Optician and optometrist outlets.

Source: Government of Ireland.

Table A.7: Essential Retail Outlets During Lockdown 3 of COVID-19 Pandemic in Ireland

Retail Outlet
1. Outlets selling food or beverages on a takeaway basis, or newspapers, whether on a retail or wholesale basis and whether in a non-specialised or specialised outlet
2. Markets that, wholly or principally, offer food for sale
3. Outlets selling products necessary for the essential upkeep and functioning of places of residence and businesses, whether on a retail or wholesale basis
4. Pharmacies, chemists and retailers or wholesalers providing pharmaceuticals or pharmaceutical or dispensing services, whether on a retail or wholesale basis
5. Outlets selling health, medical or orthopaedic goods in a specialised outlet, whether on a retail or wholesale basis
6. Fuel service stations and heating fuel providers
7. Outlets selling essential items for the health and welfare of animals (including animal feed and veterinary medicinal products, pet food, animal bedding and animal supplies), whether on a retail or wholesale basis
8. Laundries and drycleaners
9. Banks, post offices and credit unions
10. Outlets selling safety supplies (including work-wear apparel, footwear and personal protective equipment), whether on a retail or wholesale basis
11. Hardware outlets, builders' merchants and outlets that provide, whether on a retail or wholesale basis: hardware products necessary for home and business maintenance or construction and development, sanitation and farm equipment, supplies and tools essential for farming or agriculture purposes
12. Outlets providing for the repair and maintenance of mechanically propelled vehicles or bicycles and any related facilities (including tyre sales and repairs)
13. The following outlets, insofar as they offer services on an emergency basis only: outlets providing hearing test services or selling hearing aids and appliances; outlets selling office products and services for businesses or for relevant persons working from their respective places of residence, whether on a retail or wholesale basis; outlets providing electrical, information and communications technology and telephone sales, repair and maintenance services for places of residence and businesses
14. Any other retail outlet that operates an online or other remote system of ordering goods for purposes of collection at the retail outlet
15. Outlets selling food or beverages whether on a retail or wholesale basis and whether in a non-specialised or specialised outlet: insofar as they sell food or beverages on a takeaway basis or for consumption off the premises; insofar as they are staff canteens operating for the exclusive use of persons working in, or at, a particular premises; or hotels or similar accommodation services, insofar as they sell food or beverages for consumption on the premises
16. Optician and optometrist outlets

Source: Government of Ireland.

Table A.8: Individual Events Associated with Divergent Incidence Rates in Commuter Counties

Commuting To	*Commuting From*	*Difference*	*Cause*
Dublin	Wicklow	Higher incidence in Wicklow from 2020-11-04 to 2020-12-02	Possibly due to an outbreak in a retirement home https://www.irishtimes.com/news/health/four-deaths-in-COVID-outbreak-at-augustinian-retirement-home-1.4436738
Dublin	Wexford	Higher incidence in Wexford from 2020-10-01 to 2020-12-26	New Ross had highest COVID-19 incidence rate – more than three times the national average
Dublin	Kildare	Higher incidence in Kildare from 2020-07-26 to 2020-08-25	O'Brien Fine Foods Factory Outbreak https://www.irishtimes.com/news/ireland/irish-news/inside-the-o-brien-fine-foods-factory-in-lockdown-kildare-1.4330267
Dublin	Meath	Higher incidence in Meath from 2020-10-06 to 2020-11-01	Dublin moved to level 3 restrictions first
Dublin	Westmeath	Higher incidence in Westmeath from 2020-04-28 to 2020-05-11	Dawn Meats Kilbeggan outbreak first/Nursing home outbreak
		Higher incidence in Westmeath from 2020-10-06 to 2020-10-27	Dublin moved to level 3 restrictions
Dublin	Laois	Higher incidence in Laois from 2020-07-24 to 2020-08-11	Laois end up in level 3
Dublin	Louth	Higher incidence in Louth from 2020-12-21 to 2020-12-27	Louth at the border when NI had surge of cases before Christmas
Dublin	Cavan	Higher incidence in Cavan from 2020-10-03 to 2020-10-26	Dublin moved to level 3 restrictions first

Table A.8: Individual Events Associated with Divergent Incidence Rates in Commuter Counties (Contd.)

Commuting To	*Commuting From*	*Difference*	*Cause*
Dublin	Offaly	Higher incidence in Offaly from 2020-05-06 to 2020-05-19	pig meat processing plant outbreak https://www.rte.ie/news/coronavirus/2020/0514/1138392-meat-processing-plants-covid-19/
		Higher incidence in Offaly from 2020-07-29 to 2020-08-13	Meat plant outbreak
Monaghan	Cavan	Higher incidence in Cavan from 2020-04-07 to 2020-04-14	Highest incidence rate in Cavan https://www.irishtimes.com/news/ireland/irish-news/covid-19-cases-in-cavan-exceed-dublin-as-incidence-in-border-counties-rise-1.4238907
		Higher incidence in Cavan from 2020-10-06 to 2020-10-26	GAA activity https://www.irishtimes.com/news/health/gaa-activity-seen-as-a-major-reason-for-cavan-covid-surge-1.4381130
		Higher incidence in Monaghan from 2020-12-21 to 2020-12-27	Unknown
Westmeath	Roscommon	Higher incidence in Westmeath from 2020-04-01 to 2020-04-16	Dawn Meats Kilbeggan outbreak
Limerick	Clare	Higher incidence in Limerick from 2020-12-18 to 2020-12-27	All Ireland Final/Nursing home outbreak – https://www.irishtimes.com/news/health/explosion-of-covid-19-infections-in-limerick-led-to-seven-deaths-at-care-home-1.4463478
Galway	Mayo	Higher incidence in Galway from 2020-10-27 to 2020-12-18	Moycullen outbreak; source unknown https://www.the42.ie/moycullen-players-unavailable-to-galway-teams-covid-19-5232139-Oct2020/
Sligo	Leitrim	Higher incidence in Sligo from 2020-10-12 to 2020-10-31	Unknown

Table A.8: Individual Events Associated with Divergent Incidence Rates in Commuter Counties (Contd.)

Commuting To	*Commuting From*	*Difference*	*Cause*
Kildare	Offaly	Higher incidence in Offaly from 2020-05-06 to 2020-05-19	Pig meat processing plant outbreak https://www.rte.ie/news/coronavirus/2020/0514/1138392-meat-processing-plants-covid-19/
Louth	Meath	Higher incidence in Louth from 2020-12-21 to 2020-12-27	Louth at the border when NI had surge of cases before Christmas
		Higher incidence in Meath from 2020-10-06 to 2020-10-27	Unknown
Westmeath	Offaly	Higher incidence in Offaly from 2020-05-12 to 2020-05-19	pig meat processing plant outbreak https://www.rte.ie/news/coronavirus/2020/0514/1138392-meat-processing-plants-covid-19/
		Higher incidence in Offaly from 2020-07-30 to 2020-08-13	Meat plant outbreak
		Higher incidence in Offaly from 2020-12-01 to 2020-12-14	Westmeath had almost no cases
		Higher incidence in Westmeath from 2020-10-10 to 2020-10-26	Nursing home outbreak https://www.irishtimes.com/news/health/westmeath-nursing-home-says-it-is-managing-covid-19-outbreak-with-15-cases-1.4389333

Source: Authors' calculations based on CSO POWSCAR 2016, COVID-19 HPSC Detailed Statistics Profile.

Table A.9: Percentage County Commuter Flows – ↓ Origin, Destination →

	Carlow	Cavan	Clare	Cork	Donegal	Dublin	Galway	Kerry	Kildare	Kilkenny	Laois	Leitrim	Limerick	Longford	Louth	Mayo	Meath	Monaghan	Offaly	Roscommon	Sligo	Tipperary	Waterford	Westmeath	Wexford	Wicklow
	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%
Carlow	70	0	0	0	0	0	0	0	1	3	7	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
Cavan	0	75	0	0	0	0	0	0	0	0	0	4	0	2	0	0	1	5	0	0	0	0	0	0	0	0
Clare	0	0	74	0	0	0	1	0	0	0	0	0	4	0	0	0	0	0	0	0	0	1	0	0	0	0
Cork	0	0	1	96	0	0	0	5	0	1	0	0	4	0	0	0	0	0	0	0	0	3	5	0	0	0
Donegal	0	0	0	0	88	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Dublin	7	6	1	1	2	96	1	1	30	4	9	4	1	5	13	2	31	4	6	3	2	2	2	8	6	35
Galway	0	0	3	0	1	0	93	0	0	0	0	1	0	1	0	6	0	0	1	7	1	1	0	1	0	0
Kerry	0	0	0	0	0	0	0	89	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Kildare	5	1	0	0	0	1	0	0	64	1	9	1	0	1	1	0	4	1	5	1	0	0	0	3	1	2
Kilkenny	5	0	0	0	0	0	0	0	0	71	3	0	0	0	0	0	0	0	0	0	0	2	3	0	1	0
Laois	4	0	0	0	0	0	0	0	1	1	62	0	0	0	0	0	0	0	4	0	0	1	0	0	0	0
Leitrim	0	1	0	0	0	0	0	0	0	0	0	62	0	1	0	0	0	0	0	5	1	0	0	0	0	0
Limerick	0	0	19	1	0	0	1	4	0	1	1	0	87	0	0	1	0	0	1	0	0	9	1	0	0	0
Longford	0	1	0	0	0	0	0	0	0	0	0	4	0	76	0	0	0	0	0	4	0	0	0	2	0	0
Louth	0	1	0	0	0	0	0	0	0	0	0	0	0	0	78	0	6	7	0	0	0	0	0	0	0	0
Mayo	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	87	0	0	0	3	4	0	0	0	0	0
Meath	0	7	0	0	0	1	0	0	1	0	0	0	0	0	5	0	56	1	1	0	0	0	0	3	0	0
Monaghan	0	4	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	77	0	0	0	0	0	0	0	0
N. Ireland	0	1	0	0	8	0	0	0	0	0	0	1	0	0	1	0	0	4	0	0	0	0	0	0	0	0
Offaly	0	0	0	0	0	0	0	0	1	0	5	0	0	1	0	0	0	0	68	1	0	1	0	3	0	0
Roscommon	0	0	0	0	0	0	1	0	0	0	0	4	0	2	0	1	0	0	0	57	2	0	0	2	0	0
Sligo	0	0	0	0	1	0	0	0	0	0	0	13	0	1	0	2	0	0	0	3	86	0	0	0	0	0
Tipperary	0	0	1	0	0	0	0	0	0	3	2	0	2	0	0	0	0	0	3	0	0	76	4	0	0	0
Waterford	1	0	0	0	0	0	0	0	0	12	0	0	0	0	0	0	0	0	0	0	0	3	84	0	3	0
Westmeath	0	1	0	0	0	0	1	0	0	0	1	1	0	9	0	0	1	0	8	15	0	0	0	75	0	0
Wexford	3	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	1	0	83	1
Wicklow	4	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	59

Source: Authors' calculations; CSO POWSCAR 2016.

Table A.10: COVID-19 Incidence-Rate Correlation between Contiguous Commuting Counties (March 2020 – May 2021)

Destination County	*Origin County*	*Correlation*
Cork	Kerry	0.95
Dublin	Wicklow	0.94
	Kildare	0.82
	Meath	0.71
Westmeath	Longford	0.84
	Roscommon	0.83
	Offaly	0.79
Limerick	Clare	0.81
	Tipperary	0.85
Galway	Roscommon	0.79
	Mayo	0.81
Sligo	Leitrim	0.87
Waterford	Kilkenny	0.82
Louth	Meath	0.70
	Monaghan	0.90
Carlow	Laois	0.91
Kildare	Laois	0.81
	Offaly	0.78
Kilkenny	Carlow	0.87
Meath	Cavan	0.94

Source: Authors' calculations based on CSO POWSCAR 2016, COVID-19 HPSC Detailed Statistics Profile.

Table A.11: COVID-19 Incidence-Rate Correlation between Non-Contiguous Commuting Counties (March 2020 – May 2021)

Destination County	*Origin County*	*Correlation*
Dublin	Wexford	0.68
	Westmeath	0.80
	Laois	0.82
	Louth	0.86
	Carlow	0.71
	Cavan	0.74
	Offaly	0.74

Source: Authors' calculations based on CSO POWSCAR 2016, COVID-19 HPSC Detailed Statistics Profile.

Table A.12: COVID-19 Incidence-Rate Correlation between Border LEAs and Closest Northern Irish LGD (August 2020 – May 2021)

LEA	*County*	*Closest LGD*	*Corr.*	*Lagged Corr*	*LEA*	*County*	*Closest LGD*	*Corr.*	*Lagged Corr.*
Dundalk-South	Louth	NMD	0.81	0.91	Kells	Meath	NMD	0.69	0.91
Ballymote-Tobercurry	Sligo	FO	0.81	0.93	Boyle	Roscommon	FO	0.68	0.84
Sligo-Drumcliff	Sligo	FO	0.79	0.88	Drogheda Urban	Louth	NMD	0.67	0.84
Ardee	Louth	NMD	0.78	0.88	Ballyjamesduff	Cavan	FO	0.64	0.74
Sligo-Strandhill	Sligo	FO	0.77	0.89	Ballinamore	Leitrim	FO	0.61	0.77
Bailieborough-Cootehill	Cavan	FO	0.75	0.90	Granard	Longford	FO	0.60	0.71
Laytown-Bettystown	Meath	NMD	0.75	0.87	Buncrana	Donegal	DCS	0.59	0.73
Carrickmacross-Castleblayney	Monaghan	NMD	0.74	0.88	Longford	Longford	FO	0.50	0.66
Dundalk-Carlingford	Louth	NMD	0.73	0.90	Ballymahon	Longford	FO	0.46	0.65
Carrick-on-Shannon	Leitrim	FO	0.73	0.82	Lifford-Stranorlar	Donegal	DCS	0.45	0.52
Ballybay-Clones	Monaghan	FO	0.72	0.87	Carndonagh	Donegal	DCS	0.45	0.56
Manorhamilton	Leitrim	FO	0.71	0.84	Letterkenny	Donegal	DCS	0.37	0.51
Drogheda Rural	Louth	NMD	0.71	0.87	Donegal	Donegal	DCS	0.37	0.52
Monaghan	Monaghan	ACBC	0.70	0.76	Milford	Donegal	DCS	0.25	0.36
Cavan-Belturbet	Cavan	FO	0.70	0.83	Glenties	Donegal	FO	0.25	0.42

Source: Authors' calculations based on CSO POWSCAR 2016, COVID-19 HPSC Detailed Statistics Profile, Northern Ireland Department of Health.

Note: NMD – Newry, Mourne and Down, FO – Fermanagh and Omagh, ACBC – Armagh City, Banbridge and Craigavon, DCS – Derry City and Strabane.