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# The impact of University reopenings on COVID-19 cases in Scotland\*

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## Abstract

This paper estimates the impact of University reopenings in Scotland in Autumn 2020 on COVID-19 cases in Scottish neighbourhoods. We geolocate all student halls in Scotland, and merge this data with neighbourhood-level case data. We employ a local differences-in-differences strategy and tackle two research questions. First, we ask what was the impact of the start of semester on cases in the student neighbourhoods? Next, we turn our attention to the spillover of cases in the nearby communities to student neighbourhoods. University semester start dates in Scotland are staggered over the month of September, and we deal with this by focusing on each start cluster, as well as implementing the [Callaway and Sant'Anna \(2020\)](#) estimator. We find a substantial and persistent increase in cases in areas containing halls and evidence of persistent spillovers. These effects are linked to the group of Universities that started on 14th September, which include large Universities located in the major urban areas. The cases began to rise on 21st September, with 100 extra cases per 100,000 per day, and peaked a week later with 400 additional cases per 100,000 per day, after which they started declining, but persist until the Autumn tightening of coronavirus restrictions bit in November, two months after the restrictions were enacted. Our results invite a re-think of how close contact activities may safely resume.

**Keywords** Covid Economics, University reopenings, cases, Public Health

**JEL Codes** I10, I18, I28

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# 1 Introduction

Understanding the effect of restrictions on the spread of pandemics is essential to inform decision-making models for the near future and future epidemic episodes. A controversial restriction which has been adopted world wide is the closing of Primary and Secondary education. There is a nascent literature which evaluates the impacts of school reopenings on COVID-19 transmission, and the evidence is mixed.(Goldhaber et al., 2021; Bravata et al., 2021; Harris et al., 2021; Courtemanche et al., 2021; Isphording et al., 2021; von Bismarck-Osten, Borusyak, and Schönberg, von Bismarck-Osten et al.) An overlooked group in the policy discussion has been the role of Higher Education in the spread of COVID-19. This paper investigates the impact of students returning to University campuses during the start of the new academic year in September/October 2020 on transmission of the virus in the local area. During the gradual reopening of the economy during the summer, Universities Scotland, the umbrella group of all Scottish Universities, worked with the Scottish Government towards safely returning students to University campuses through the adoption of a blended teaching approach, i.e., a mix between face-to-face and online teaching, for the next academic year. In many instances, students were encouraged to move back into University towns anticipating further relaxation of rules in the autumn. There are no official statistics on how many students moved back to campuses or student halls, but reports point to some residences being at near of full capacity at the beginning of the academic year.<sup>1</sup>

While a number of papers examined the effect of school reopenings on the spread of COVID-19 infections in the community, we are not aware of any study looking at the impact of university reopenings. Universities and colleges contribute significantly to the national and local economy, adding £4.6 billion to the Scottish economy, employing 36,850 people and supporting another 36,050 jobs across the country through their supply chains and the expenditure of staff and students<sup>2</sup>. However, during the pandemic, these benefits must be weighed against the costs associated with the potential exposure of the public to COVID-19, including hospital capacity, health risks, and long-term health issues.<sup>3</sup> University reopenings are likely to pose higher infection risks to the broader community than school reopening because of several factors associated with the nature and degree of interactions between students, staff, and the local community. First, a large number of national and international students are likely to move into University towns and campuses a few days before the start of the term, increasing the chance of imported cases into communities. Epidemic modelling stresses that higher education settings are likely to experience intra-organisational transmission, citing shared accommodation and spaces (Christensen et al., 2020). Students tend to live in multi-occupancy

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<sup>1</sup><https://www.bbc.co.uk/news/uk-scotland-54575788>

<sup>2</sup><https://www.ucu.org.uk/article/10924/Study-shows-Scotlands-universities-support-tens-of-thousands-of-jobs-and-generate-billions-for-the-country>

<sup>3</sup><https://www.nhs.uk/conditions/coronavirus-covid-19/long-term-effects-of-coronavirus-long-covid/>

households or university halls, which may also be located across urban areas, tend to commute and use public transport and have a high propensity to interact socially. This is why UK COVID-19 modelling by the Scientific Advisory Group for Emergencies (SAGE) concluded that ‘Higher Education could amplify local and national transmission’(SAGE, 2020). The risk to the wider community may be accentuated by the higher proportion of asymptomatic cases among younger age groups, meaning that cases and outbreaks are likely to be harder to detect among student populations (SAGE, 2020).

We estimate the impact of Scottish University reopenings in autumn 2020 on COVID-19 spread to the wider community using hand-collected information on locations of students halls combined with daily neighbourhood data on confirmed COVID-19 cases from Public Health Scotland.<sup>4</sup>

We do so by addressing two related research questions. The first research questions asks whether we can observe increase in cases within locations containing student halls that are attributable to Universities reopenings. A rise in cases in these locations will be taken as evidence of direct infections among students, first and foremost, and staff members. Some of these cases, however, might be found among local-area residents (we call this baseline analysis). The second research question addresses this potential spillover of COVID-19 from student halls to the wider community and adjacent areas (i.e., spillover analysis).

We draw from the differences-in-differences literature and employ an event study approach that compares *daily* positive COVID-19 cases between neighbourhoods over the period 10th August 2020 to 21st January 2021. To study the spread of the virus within locations with student halls, we contrast daily cases in neighbourhoods characterised by the presence of student halls with cases found in immediately adjacent neighbourhoods, i.e., areas that are located  $k$  kilometres from the areas containing the student residences. To evaluate potential spillovers to more distant areas, we employ a ‘donut’ approach. We compare the cases occurring in areas adjacent to those neighbourhoods where halls are located (the inner ring of the donut) to the their contiguous areas (the outer ring donut areas). The locations of the student halls are excluded from this analysis (i.e., they are the donut hole). In other words, the inner ring of the donut consists of those areas within  $k$  kilometres from the nearest hall that previously acted as a comparison group and the outer ring donut areas include units that are within  $2k$  kilometres of the student halls. Note that this donut analysis addresses concerns about the

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<sup>4</sup>The concept of neighbourhood employed here are the Scottish Intermediate Zones. These are geographical units created by the Scottish Government for censal reasons. Their size varies. As of 2019 they contained between 900-10,500 residents and an urban neighbourhood measures 1.4km<sup>2</sup>, on average. These geographical units are particularly suitable for our analysis. Public Health Scotland publishes the seven-day count of positive cases for each day instead of the actual number of cases per day. The reason behind this is twofold. First, it protects confidentiality as the number of cases can be very small within these areas. Second, it reduces the variability by smoothing the time series. Using this measure does not impact our analysis as we are estimating the difference in cases between statistically similar areas for each day in our sample. For simplicity, we refer to this variable as ‘daily’ cases. More details can be found in the Data section 2.2.

<sup>4</sup>We experiment with different values of  $k$ , from 1 to 5km.

potential violation of the Stable Unit Treatment Value Assumption (SUTVA) arising from the baseline analysis as the comparison group areas may not represent a valid counterfactual because of contamination and spillovers.

The local dynamic differences-in-differences approach allows the assessment of pre-treatment trends, i.e., to test whether there is a systematic difference in daily cases across neighbourhoods before University reopenings, while also accounting for the gradual spread of infections. This strategy has other advantages. It relaxes the single treatment effect of standard differences-in-differences and explicitly accounts for incubation periods, testing delays, and multiple rounds of transmissions. Every model includes day and neighbourhood fixed effects (two-way fixed effects estimator, TWFE) and additionally controls for differences in baseline health and socio-demographic characteristics at neighbourhood level (including the proportion of over 50s, overcrowded housing and disability rates from the Scottish Indices of Multiple Deprivation interacted with month time trend) and a weekly measure of public transport mobility that vary at the local authority level.

Estimates from TWFE specifications such as these may be biased because the start of the autumn term varies for each university and hence neighbourhood (see for example: [Goodman-Bacon, 2018](#); [Callaway and Sant’Anna, 2020](#); [Sun and Abraham, 2020](#); [Roth and Sant’Anna, 2021](#)). To address this, we run a series of heterogeneous TWFE models, i.e., we estimate separate event studies according to the term start date. Four start-of-the-semester dates generate four different sets of estimates for the increase in cases within areas containing halls relative to the nearest neighbourhoods.<sup>5</sup>

We find a substantial increase in COVID-19 cases in areas where halls are located, compared to their neighbours, in the second half of September (peaking at around 28th September). The heterogeneity TWFE analysis confirms that the large rise in cases detected in September is linked to the group of Universities opening on 14th September, which include large Universities in urban campuses of Glasgow and Edinburgh. The delay between the term start dates and the wave of cases is due to lags between exposure and symptoms that are highlighted by the epidemiological literature that finds about 3-5 days of incubation periods and another 5-14 days before symptoms appear ([Lauer et al., 2020](#); [Qin et al., 2020](#); [Chun et al., 2021](#)).<sup>6</sup> For the group starting on 14th September, our estimates show a sharp increase in cases from 21st September, a rise equivalent to an additional 100 cases per 100,000 relative to their 1km nearest neighbours. The wave peaks at an additional 400 cases per 100,000 per day on 28th September, from which it declines until 19th October. The decline seems to suggest that the measures adopted on 22nd-23rd September had begun to have an effect. These measures included the prohibition of household mixing, a 10 pm

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<sup>5</sup>As further robustness, we implement the doubly robust estimator of [Callaway and Sant’Anna \(2020\)](#), which substantially confirms the results from the heterogeneous TWFE models.

<sup>6</sup>Note that students were allowed to arrive in their halls one or two weeks prior to the start date. See Section 2 for more information.

curfew for pubs and restaurants, and measures implemented by the Universities including the isolation of hundreds of identified and suspected cases and their contacts in halls and the requirement to avoid socialising in pubs and restaurants. This heterogeneity analysis adds another crucial insight as it reveals that, although the decline from the peak is apparently rapid, the number of cases remains stubbornly higher relative to their contiguous areas until the end of November, with these areas reporting an extra 100 cases per 100,000 per day.

We find evidence of spillovers with the transmission of the virus extending beyond areas containing halls. Those locations nearest to student halls see an increase in cases (relative to their surrounding areas) approximately one week after the spike that was detected in the students' neighbourhoods. The increase in cases represents roughly an additional 20-80 daily cases per 100,000 and persist until the end of November. This represents a 20-50% increase in cases between the inner and the outer donut.

These results are important because the estimated increase in cases occurred in a context of relatively low prevalence and with several Government measures still in place to contain the virus. Scotland was cautious in reopening the economy after the national lockdown that lasted for three months, from the end of March to the end of June. The reopening was occurring while at the same time maintaining several public health measures in place, including mandatory mask-wearing in shops and public transport, physical distancing rules in indoor spaces, restrictions about indoor gathering and household mixing. Our analysis suggests that, even against this backdrop, Student in migration into student halls represented a risk for areas hosting the halls and for their surroundings. The outbreaks were ultimately dealt with, but the adverse direct and indirect health effects and the containment measures adopted were socially costly.

These findings provide valuable insights for the academic year 2021/22. While the mass vaccination program is underway in Scotland, our research invites a re-think of how close contact activities at Universities can safely resume.

This paper is structured as follows. The following section 2 describes the evolution of the pandemic in Scotland from March 2020 to January 2021 and the data used to analyse the spread of the virus after University reopenings in the autumn 2020. Section 3 detailed the empirical strategy adopted and Section 4 presents the results. Finally, section 5 highlights contributions, potential policy implications and current ongoing work aimed at expanding the analysis to cover mortality.

## 2 Context and Data

This section will provide a background of the COVID-19 situation in Scotland since March 2020, with particular reference to local and national restrictions, as well as guidelines and actions adopted by the Scottish Universities. This is followed by a description of the key data

exploited in the analysis.

## 2.1 COVID-19 in Scotland

The first positive case of COVID-19 in Scotland was confirmed and announced on 1st March 2020.<sup>7</sup> Likely, the virus was already in circulation in the country well before then as Scotland's testing strategy was in its infancy, and the actual number of infections would have been vastly higher. A few days later, several Scottish Universities were handling the first cases of students testing positive for the virus, and quickly announced measures for containment which included special arrangements for online assessments and plans to transfer teaching to online delivery by or during the week commencing 20th March 2020.<sup>8</sup> On 23rd March, the UK Prime Minister announced a set of very stringent national restrictions, the "lockdown", that applied to all the nations within the UK, including Scotland. This nationwide lockdown included the closure of all non-essential shops, outdoor gyms and places of worship, as well as the prohibition of social events and the gathering in public spaces.

The restrictions also included the closure of schools, Colleges and Universities. By that date, however, most University students already left or were about to leave their University's accommodations as the Scottish Universities were operating online and continued to do so for the remainder of the academic year. Those students still living in University halls were subject to the same restrictions as the rest of the population<sup>9</sup>, which meant studying remotely from home and going outside to exercise once a day or to buy food. Universities provided essential services for students on campus throughout this period.<sup>10</sup>

Quickly thereafter, the first wave was underway. Daily cases rapidly increased from 70-80 just before the lockdown to over 350 for most of April. The number of cases reported arguably underestimated the severity of the transmission, given the lack of testing capacity at the onset of the pandemic. However the exponential increase in the observable figures was indicative of a troublesome situation. At the same time, hospital admissions and deaths rose at a fast pace, the rates of both going from zero to their first wave peak in a matter of a four weeks. The death rate lagged behind the hospital admissions rate, but only by a fortnight - an indication of the fast progression of this disease in the sickest patients. The national lockdown brought the spread under control, but it took about two months for the number of hospitalisations to decline to March levels. By the end of May, the number of patients in intensive care had fallen by 80% since the peak. Deaths where COVID-19 was mentioned on the death certificate declined for four consecutive weeks. Excess deaths rose from mid-March, peaking to 750-880 weekly excess deaths, equivalent to 40% extra deaths for the first three

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<sup>7</sup><https://www.gov.scot/publications/novel-coronavirus-covid-19-update/>

<sup>8</sup><https://www.bbc.co.uk/news/uk-scotland-51880666>

<sup>9</sup>The UK Government's message was "Stay at home. Protect the NHS. Save lives".

<sup>10</sup><https://www.gov.scot/news/colleges-and-universities-preparing-for-phased-return/>



weeks in April.<sup>11</sup> Deaths from all causes declined steadily from mid-April and were back to the previous five-year average by mid-June, which can be taken as the end of the first wave.<sup>12</sup>

These positive trends led to the implementation of a route map out of lockdown. The route map, published on 21st May, under the title *Framework for Decision Making: Scotland's Route Map through and out of the crisis* set out the criteria to gradually lift lockdown restrictions by following four phases.<sup>13</sup> The route map also marked a slightly divergent path out of lockdown from the rest of the UK. A path characterised by a more cautionary approach than England.

Under the Scottish Government's route map, universities and colleges were to return to campus for the 2020/21 academic year and provide flexible blended digital and face-to-face teaching while adhering to public health measures, including physical distancing and enhanced hygiene measures. On 27th May, the Government announced preparations for the phased return to campus activities. The document left the details of arrangements for learning and teaching to individual institutions.<sup>14</sup>

Further restrictions were relaxed gradually between the end of June and mid-July. This phase was marked by, first, the reopening of high street shops followed by, the reopening of restaurants, pubs, cinemas and holiday accommodation under physical distance and strict hygiene measures on 15th July. Concerning Universities, teaching, learning and assessment was to continue online while lab research was allowed to be back on campus at the end of June, subject to physical distancing.<sup>15</sup>

Over the summer, Scottish Universities' plans were characterised by efforts to welcome students back to halls with a combination of measures ranging from physical distancing rules (of one or two meters depending on the level of risk and according to Scottish Government guidelines), the creation of 'students bubbles', and staggered arrival in the campus. The communication to students varied across the Institutions but broadly included references to blended teaching. Controversies arose later about how plans were communicated to students by some Universities that recommended coming back to campus more strongly than others.<sup>16</sup>

Primary Schools and high schools reopened on 11th August, with most face-to-face activities across Scotland starting in the week beginning 18th August.

The gradual move out of lockdown initiated at the end of May was interrupted in Aberdeen and Glasgow following local outbreaks. On 5th August, restrictions including the closure of restaurants, limits to indoor household visits, and travel restrictions to and from the city

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<sup>11</sup> Given the limited ability to test, excess deaths are the best measure to assess the impact of COVID-19 during the first wave. Excess deaths are computed as the difference between total deaths in a week and the average deaths from the previous five years in the same week.

<sup>12</sup> <https://data.gov.scot/coronavirus-covid-19/detail.html#deaths>

<sup>13</sup> <https://www.gov.scot/publications/coronavirus-covid-19-framework-decision-making-scotland-route-map-through-out-crisis/>

<sup>14</sup> <https://www.gov.scot/news/colleges-and-universities-preparing-for-phased-return/>

<sup>15</sup> <https://www.gov.scot/publications/coronavirus-covid-19-framework-decision-making-scotland-route-map-through-out-crisis-phase-2-update/pages/5/>

<sup>16</sup> <https://www.bbc.co.uk/news/uk-scotland-54575788>



were implemented in Aberdeen. Measures limiting household gatherings were introduced in Glasgow and nearby local authority areas (East Renfrewshire and West Dunbartonshire) on 1st September, which were then extended to other nearby areas (Renfrewshire and East Dunbartonshire) by mid-September. It is important to note that these local restrictions did not include school closures nor slowed down the reopening of the University campuses.

Following Scottish guidelines, Universities introduced face covering mandates within their own buildings and maximum class size rules. They also took a range of extra precautions that included specific COVID19 inductions for staff and students, developing apps to track staff and student movement on and around campus and within buildings supporting Scotland's contact tracing scheme. To allow a safe quarantine, most of the Universities made halls and private accommodations available to students arriving from outside the UK, or from hotspots across the UK, two weeks ahead of the start of term.<sup>17</sup>

Unfortunately, the infection rate began to rise steeply in September with Public Health Scotland figures showing a rise in cases among younger people, in concomitance with students returning to halls.<sup>18</sup> In mid-September, more than 200 students across Scotland were testing positive and entire student households asked to self-isolate and threatened with disciplinary actions in case of non-compliance.<sup>19</sup> The Scottish Government gradually began to re-introduce a number of tighter restrictions nationally and locally. First, the Government limited and then prohibited indoor households gathering. On 23rd September a 10pm curfew was imposed on pubs and restaurants. The next day, and in response to outbreaks stemming from campuses, Universities introduced more stringent measures for their students, requesting students to avoid outdoor activities and pubs, and threatening disciplinary actions.<sup>20</sup> These actions were met with resentment by student unions and trade unions and were perceived as discriminatory.<sup>21</sup> More controversies arose in the following days with some commentators denouncing Universities as having encouraged students to return to halls and then blaming students for the inevitable increase in infections. In response, Universities Scotland outlined further support measures including regular check-ins on those self-isolating and assistance with food and laundry provision. The guidelines explicitly allowed for the return home on a permanent basis for students who wished to do so.

Hospital admissions increased by almost 80% in a matter of a few days at the beginning of October, with a particularly rapid increase among the elderly. In response to this second wave, the Scottish Government introduced new restrictions planned to last for two weeks, from 9th October to 25th October, but that resulted being in place until the beginning of

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<sup>17</sup><https://www.universities-scotland.ac.uk/sharedayrestartmsg/>

<sup>18</sup>Outbreaks were reported in shared students accommodation in all the major urban areas.<https://www.bbc.co.uk/news/uk-scotland-56399043>

<sup>19</sup><https://www.bbc.co.uk/news/uk-scotland-54268780>

<sup>20</sup><https://www.universities-scotland.ac.uk/preventing-spread-of-coronavirus-in-universities/>

<sup>21</sup><https://www.ucu.org.uk/article/11021/UCU-response-to-rules-banning-Scottish-students-from-socialising?list=1676>

November, when a new five-tier COVID-19 system came into effect. For most of the Scottish people living in the ‘Central Belt’ – the area encompassing Edinburgh, Stirling and Glasgow – this amounted to a mini-lockdown, with non-essential shops and pubs being forced to closed and schools closed because of the planned two-week October school holiday.<sup>22</sup>

The new five-tier system came into force from 2nd November, when temporary curbs on the hospitality trade were due to expire. The five levels indicated different levels of protection that might be needed based on different levels of transmission for the virus. Most of Scotland was placed under tier two or three. On 20th November, 2.3 million Scots living in the Central Belt area were placed under tier four, with the closure of non essential shops and restaurants. The restrictions were eased on 11th December when non-essential shops reopened. A few days later, nine cases with a more infectious variant of COVID-19 were reported in Scotland. On 19th December, the Scottish Government tightened the Christmas rules significantly and announced that level four restrictions would be applied to all of Scotland from 26th December. The number of cases continued to climb and the Scottish Government announced a full lockdown for mainland Scotland from 5th January with a new legal requirement forbidding anyone from leaving their home except for essential purposes. On 8th January Scottish Government announce that University students will be taught online throughout January and February.

The second national lockdown, together with the mass vaccination programme that started on 8th December, was successful in reducing the infection rate. Schools reopened in February, March and April, following a staggered approach. Universities around Scotland continued offering online teaching for the remainder of the term. Table A1 in the Appendix summarises the key measures adopted over the summer and autumn 2020 in Scotland.

## 2.2 Data

This paper studies data at the Scottish Intermediate Zone level. These statistical units aggregate Scottish Data Zones, which are the lowest level unit of aggregation for Scottish official statistics. According to the most recent estimates by the National Records of Scotland<sup>23</sup>, there are 5.4 million people living in Scotland spread across 1,279 Intermediate Zones. Intermediate Zones can be considered to represent neighbourhoods and the current boundaries were created for the 2011 census, and were designed to range in size between 2,500 and 6,000 household residents. However, a decade out, the boundaries have not been redrawn, and as of the latest population estimates for 2019, they are now found to include between 900-10,500 individuals.<sup>24</sup> The largest neighbourhood currently includes Finnieston and Kelvinhaugh in

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<sup>22</sup>For the rest of Scotland these restrictions amounted to banning alcohol sales in pubs and restaurants and a 6 pm curfew.

<sup>23</sup><https://www.nrscotland.gov.uk/statistics-and-data/statistics/scotlands-facts/population-of-scotland>

<sup>24</sup>The term “neighbourhoods”, “locations”, “areas”, and “Intermediate Zones” are used interchangeably throughout the paper. Note that Intermediate Zones are “intermediate” because they sit between the 6,500

Glasgow, which hosts three University of Glasgow student halls and eight private-provider student halls of residence.

**Student halls of residence** Student halls of residences are typically provided by universities for their first year students, or international students.<sup>25</sup> Student halls are usually purpose-built university owned buildings of multiple occupancy with shared amenities (such as kitchens and bathrooms). In Scotland there are more than half a million students in Further and Higher Education, of which approximately 8% live in student halls of accommodation. 45% of all students in accommodation are comprised of first year undergraduate degree students (Scottish Parliament, 2020). We hand collected the addresses of all halls of residence for each Scottish university. In general, students in the later years of study tend to move out from university managed accommodation and into privately rented accommodation. In recent years, with the expansion of university uptake this has caused significant housing pressures in cities, as students corner the private rental market and crowd out locals from the rental market. In Scotland there have been two complementary policy responses to this phenomenon. First, since 2000 any privately rented property that for the purposes of law can be construed as being a House of Multiple Occupancy has to be licensed.<sup>26</sup> Secondly, due to the increased pressure between licensing private properties and the increases in student numbers there has been an explosion in privately provided student halls. These are often built by housing groups or chains that run these nationally. These private halls tend to fall outside university regulations, though some may restrict themselves solely to taking students from a single university. We geolocated all private halls in Scotland by exploiting search engines for student accommodation. Figure 1a shows the geographical spread of these two types of halls. Note that dots shown in red are the exact locations of halls, whilst the areas shaded in dark blue represent the student hall neighbourhoods themselves, and the light blue denote those neighbourhoods (whose centroid is) within 5km of a student hall.

Though pictured we exclude from our analysis two universities. These are the University of the Highlands and Islands (UHI) and Scotland’s Rural College (SRUC) which is an agricultural college that does further and postgraduate training. Both of these are excluded as their campuses are primarily in rural settings where COVID-19 was not as much of a concern, as outlined earlier. Our primary unit of analysis is the Intermediate Zone, or neighbourhood.

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‘Data Zones’ (the smallest Scottish statistical unit areas consisting of 350 households) and the 32 local authorities or councils. For more information see: <https://data.gov.uk/dataset/133d4983-c57d-4ded-bc59-390c962ea280/intermediate-zone-boundaries-2011>.

<sup>25</sup>Students may choose to live in halls, or not. There is no formal requirement but usually most undergraduates from outside the region where the university is located will move into halls to develop peer networks.

<sup>26</sup>This is a household of at least 3 (unrelated) people who share toilet and kitchen facilities. Legislation Regulating the granting of Houses of Multiple Occupancy (HMO) in Scotland fall under the purview of The Civic Government (Scotland) Act 1982 (Licensing of Houses in Multiple Occupation) Order 2000 and were more recently tightened up with the introduction of the Housing (Scotland) Act of 2006.

<sup>26</sup>In practice with geographic segregation of universities, it is unlikely that a student would live at halls nearby a university they are not attending.

For the most part this characterisation is appropriate. However, when looking at the size of Intermediate Zones in rural areas this quickly ceases to hold. Using the Scottish Government 2016 Threefold Rural Classification, the discrepancy in size becomes clear. The average size of an urban neighbourhood is 1.4 km<sup>2</sup>, for areas deemed to be accessible rural this is 8.4km<sup>2</sup>, and for remote rural areas this balloons to 1,400 km<sup>2</sup>. The average size of the excluded Intermediate Zones for SRUC and UHI is 409 km<sup>2</sup> as such we felt that this could no longer be characterised as the same scale of neighbourhood. For this reason, in Figure 1a we do not shade in the neighbourhoods of the halls belonging to these universities. Figures 1b-1f plot student halls in their neighbourhoods for the cities in Scotland. Note that the comparison units are drawn from nearby neighbourhoods whose centroid falls within the 5km radius from a student hall. This is done deliberately to ensure that neighbourhoods that are comparable are used in the analysis. In locations such as Stirling, and Paisley (bottom left hand cluster of Glasgow image) some of the neighbourhood boundaries are of a rather large size, and the centroid of these areas is outwith the radius of comparison units selected. It is also worthwhile noting that in Figure 1e the seemingly large gap between Dundee and Fife is due to the River Tay, and whilst there is a large gap between these locations and the comparison neighbourhoods drawn on the Fife coast, these represent Newport-on-Tay, Wormit and Woodhaven, which are commuter neighbourhoods of Dundee connected by the (unseen) Tay Bridge.

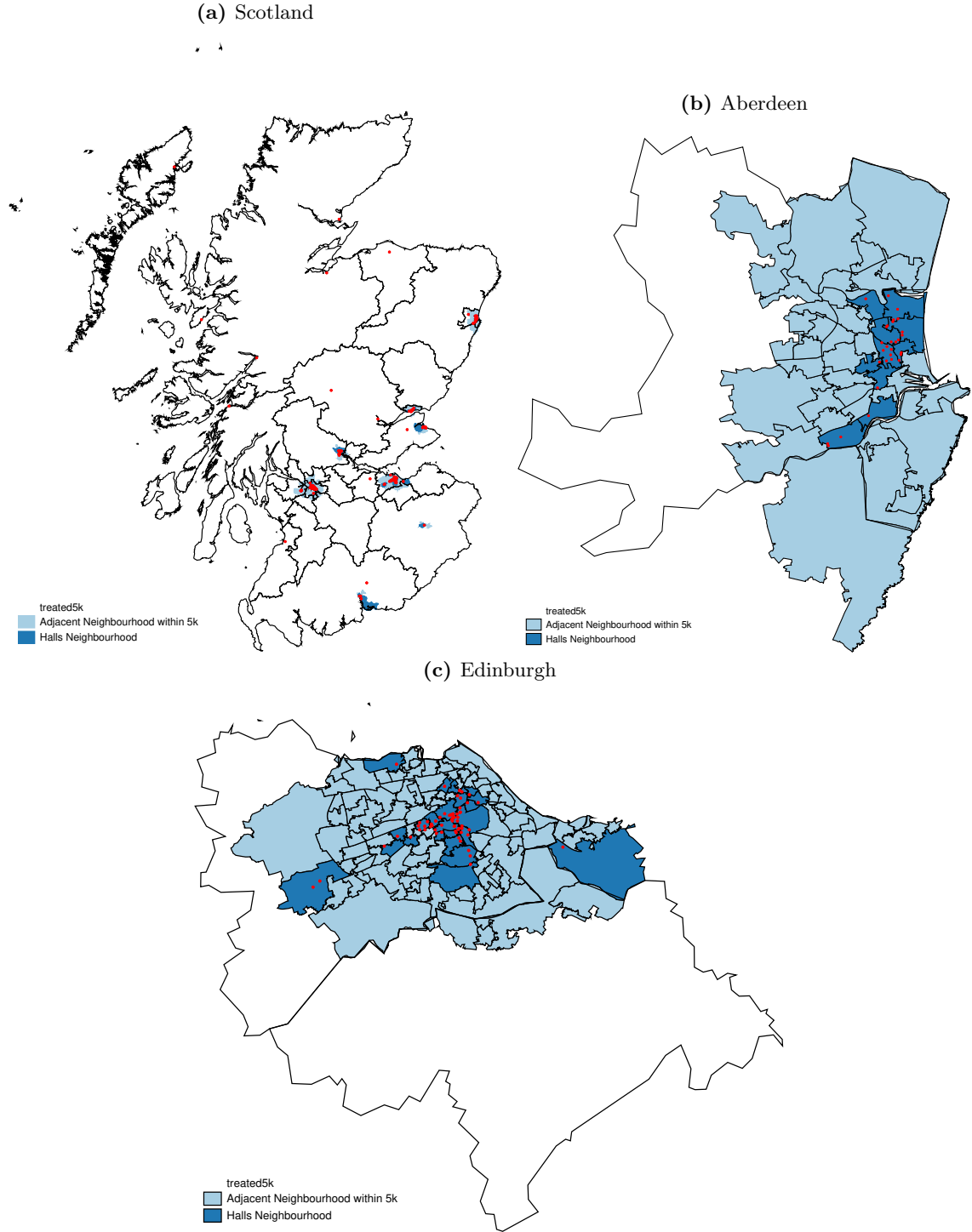
In our analysis we focus on the direct effect of student in migration into student halls. However, we are also interested in estimating the onward effects of COVID-19 transmission on neighbouring areas. To this aim Figures 2b-2f plot these areas for what we term the spillover/donut analysis. We exclude the donut centre, that is the neighbourhood that houses student halls, and we compare the inner donut (shaded light) and compare it to the next nearest neighbourhoods (shaded dark). We make these comparisons for a series of moving rings, or different sizes of donuts. The Figures represent the maximum extent we consider, that is the neighbourhoods whose centroids are 0-5km of student halls, which are contrasted to those neighbourhoods 5-10km from student halls.<sup>27</sup>

Universities begin their autumn Semesters in a staggered fashion throughout the months of September and October. Table 1 provides the start date for autumn 2020 of all Universities in Scotland. As can be seen, Universities are concentrated across a number of cities in the Central Belt (viz. Edinburgh, Glasgow, Stirling) Dundee and Aberdeen. In cities where there is more than one University, there is the possibility that student halls, either university provided, or private from two separate universities may co-exist in the same neighbourhood. This occurs in the Perth Road Neighbourhood of the West End of Dundee, for example. For the purposes of our analysis, these neighbourhoods are thought of as treated when the earliest university begins, so in this example, this would be when Abertay University begins their semester on 14th September.

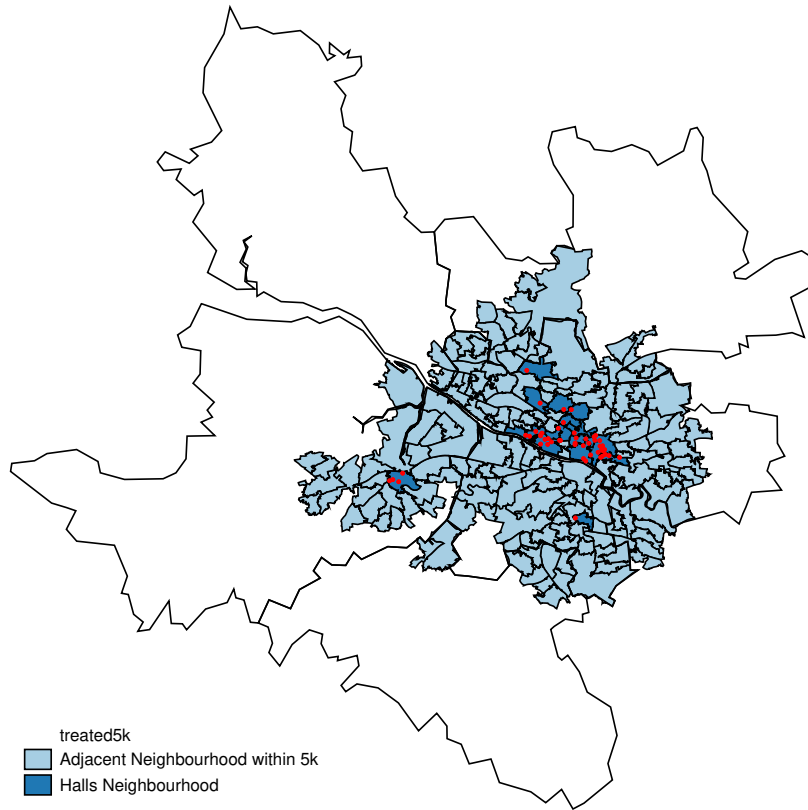
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<sup>27</sup>Please note in Figure 2c the seemingly floating comparison groups are the commuter towns of Burntisland and Dalgetty Bay which are connected by rail and road links to central Edinburgh.

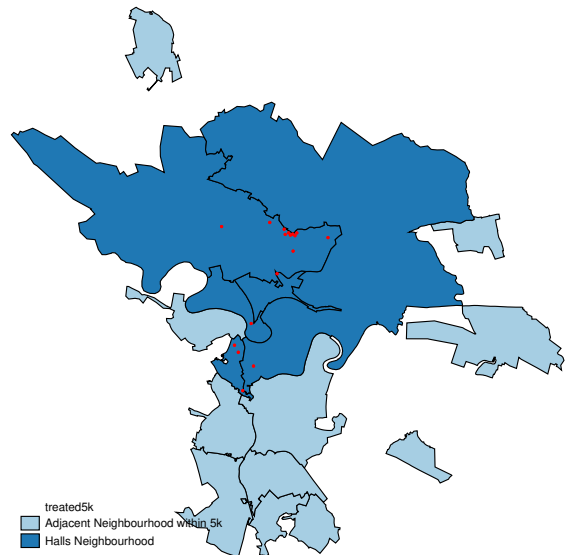
**Figure 1:** Intermediate Zones with student halls, and those within 5km of a student hall



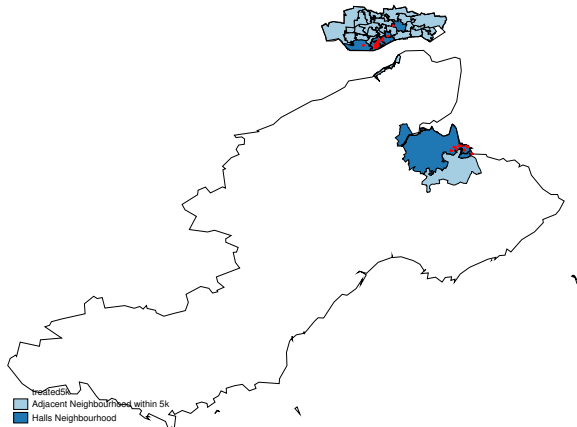
(d) Glasgow



(f) Stirling

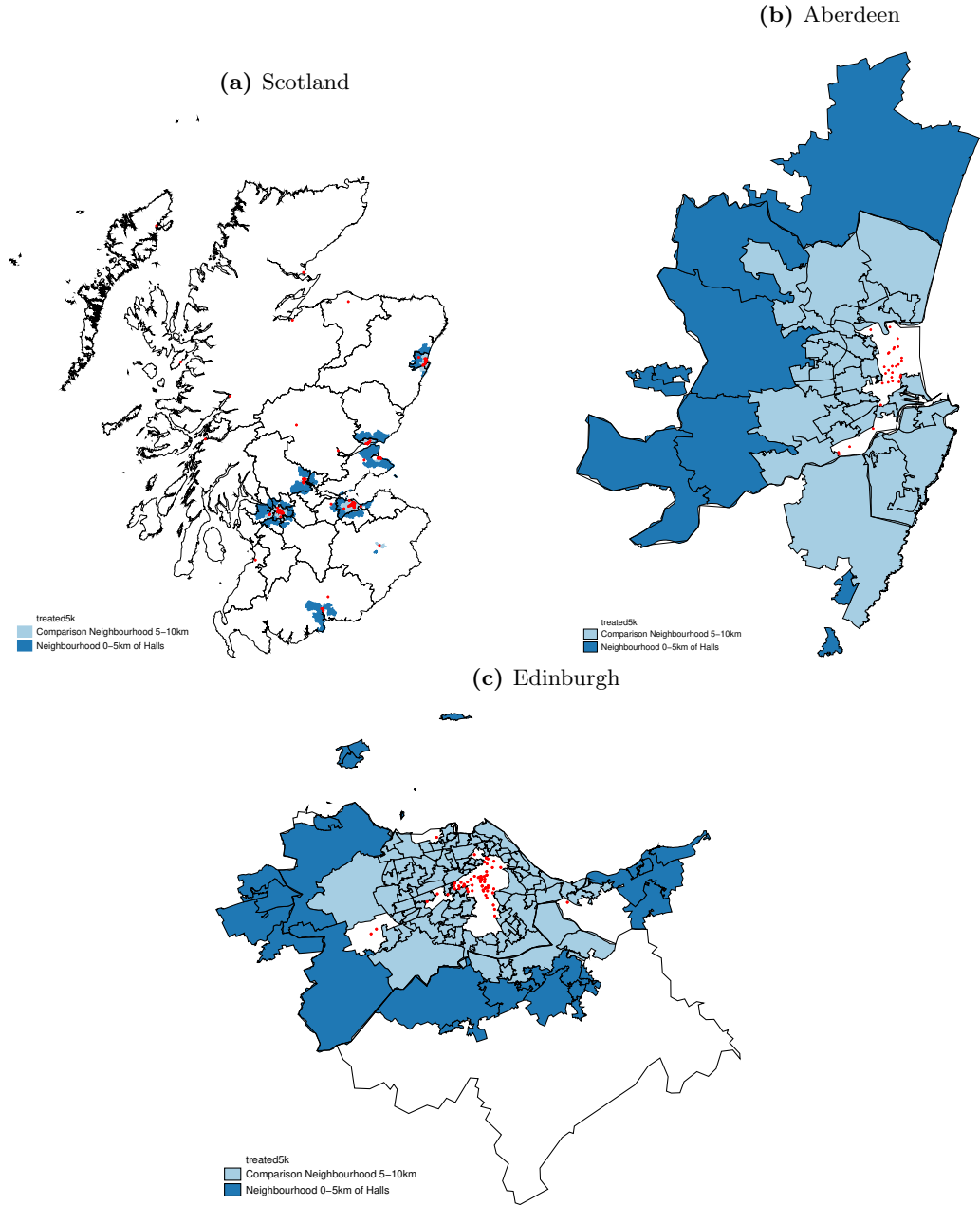


(e) Dundee & Fife



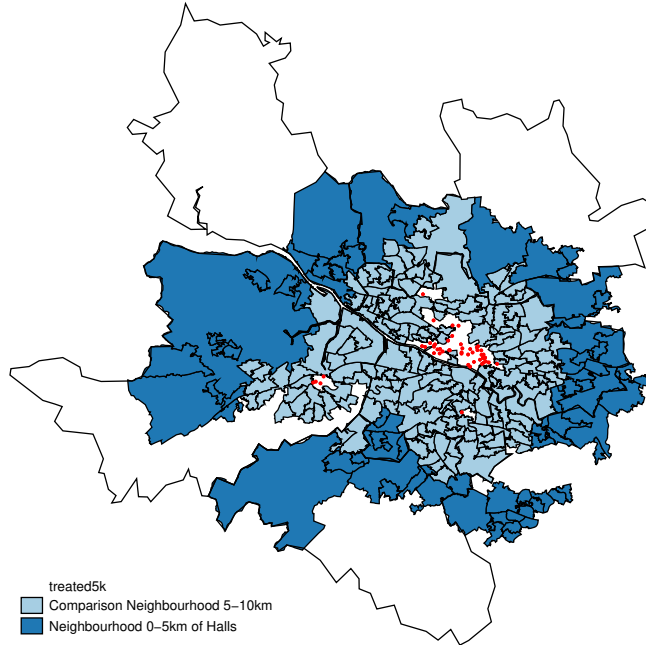
NOTE: Figures show neighbourhoods which have student halls, marked as red dots. Student neighbourhoods are shaded dark, whilst those who serve as comparison groups are shaded light. Subfigures b-f denote the neighbourhoods for each of the major Scottish cities. Note that the comparison areas are selected as having the centroid of the neighbourhood within 5km of student halls.

**Figure 2:** Intermediate Zones for spillover analysis; neighbourhoods within 0-5km of student halls vs neighbourhoods located 5-10km from student halls

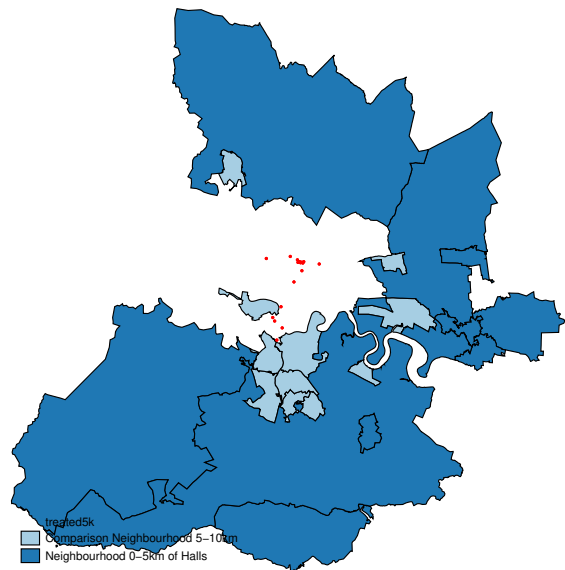




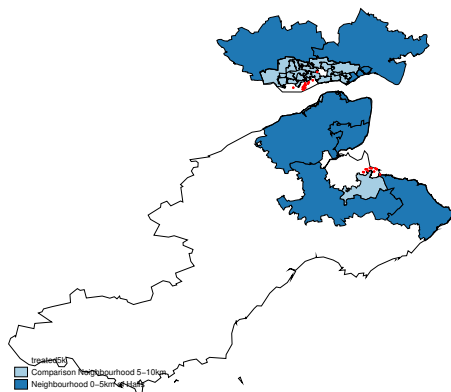
(d) Glasgow



(f) Stirling



(e) Dundee & Fife



NOTE: Figures show neighbourhoods which have student halls, marked as red dots. Subfigures b-f denote the neighbourhoods for each of the major Scottish cities. Blank areas within each figure denote areas where student halls are located (they represent the donut hole). Neighbourhoods within 0-5km of student halls are shaded light, whilst those locations that serve as comparison groups are shaded dark. Note that the areas are selected as having the centroid of the neighbourhood within 0-5km of student halls. The comparison group areas are selected as being 5-10km from student halls, and similarly exclude some areas where the centroid of the neighbourhood falls outside the 10km radius.

**Table 1:** Start dates for Universities in Scotland, Autumn 2020

University	Start date	Locality
Edinburgh Napier University	07 Sept 2020	Edinburgh
Heriot Watt University	07 Sept 2020	Edinburgh & Campus in Scottish Borders
Queen Margaret University	07 Sept 2020	Edinburgh
University of the Highlands and Islands	07 Sept 2020	Multiple Sites
Glasgow School of Art	14 Sept 2020	Glasgow
Abertay University	14 Sept 2020	Dundee
University of Edinburgh	14 Sept 2020	Edinburgh
University of Glasgow	14 Sept 2020	Glasgow
University of St Andrews	14 Sept 2020	St Andrews (Fife)
University of Stirling	14 Sept 2020	Stirling
University of Strathclyde	14 Sept 2020	Glasgow
Glasgow Caledonian University	21 Sept 2020	Glasgow
Robert Gordon University Aberdeen	21 Sept 2020	Aberdeen
Royal Conservatoire of Scotland	21 Sept 2020	Glasgow
SRUC	21 Sept 2020	Aberdeen
University of Aberdeen	21 Sept 2020	Aberdeen
University of Dundee	05 Oct 2020	Dundee
University of the West of Scotland	05 Oct 2020	Paisley (Greater Glasgow)

NOTE The table shows the start dates of each university across Scotland, and their nearest proximate location. For the University of the Highlands and Islands, the university is comprised of 13 different sites throughout the country. However, as outlined in the text this university is excluded from the present analysis as the locations tend to be in rural areas that had low prevalence of COVID-19 infections, and where the interpretation of Intermediate Zones as neighbourhoods breaks down due to the low population density.

**Measuring COVID-19 spread** The data we exploit for this analysis comes from Public Health Scotland (PHS) COVID-19 Open Data <https://www.opendata.nhs.scot/dataset/covid-19-in-scotland>. PHS provide daily cases of COVID-19 at Intermediate Zone level. The measure of cases is given as the number of cases for a given neighbourhood in the past seven days. For confidentiality purposes, where a neighbourhood has two or fewer reported cases in the previous seven day period, the information is suppressed. We treat these as zeros in our analysis. The reporting of data as a cumulative measure of cases is a means of smoothing out spikes in the data as well as protecting confidentiality of the data for a given neighbourhood. In our analysis this will not pose any issues, as we will be comparing the relative rates between neighbourhoods per day. Cases are allocated to neighbourhoods in accordance to the postcode given to the testing system. Due to the spatial aggregation of the data, there are large number of both legitimate zeros and suppressed information (which we treat as zeros). In order to make sense of the data, we convert this variable into population rates at neighbourhood level, we use the latest available population projections created for the 2019 Scottish Indices of Multiple Deprivation (SIMD).

To further account for the suppression of small numbers of positives in the data we focus on using the outcome as both levels, that is the number of cases in a neighbourhood in the past seven days per 100,000 of the local population, as well as the inverse hyperbolic sine of cases. This approach allows to interpret changes in relative percentage terms, similar to the interpretation as a logged dependent variable but gets around the well known lack of definition for  $\ln(0)$ , where the inverse hyperbolic sine is defined as  $\tilde{y} = \text{arcsinh}(y) = \ln(x + \sqrt{y^2 + 1})$ .

### 3 Empirical Strategy

#### 3.1 Local Dynamic Differences-in-Differences Analysis

This paper is focused on estimating transmission of COVID-19 in neighbourhoods surrounding student halls. We draw from the differences-in-differences literature and employ flexible event-study approaches to first explore how *daily* cases vary between locations characterised by the presence of student halls and adjacent locations. We then apply the same methodology and estimate the spillover of cases in adjacent locations as we move  $k$  kilometers away from the resident hall. We discuss potential pitfalls of this approach and estimate alternative regressions in the next section.

The approach we adopt here is based on a ‘local’ differences-in-differences analysis. First, we geolocate all the residence halls for universities and aggregate the numbers up to the Intermediate Zone level. The group of neighbourhoods that contains student halls represent the treatment group. Following Tobler’s First Law of Geography (i.e., ‘near things are more related than distant things’, (Tobler, 1970)), the comparison groups are constructed by selecting units within a  $k$  kilometre radius from each Intermediate Zone that contains one or

more student halls. This approach restricts the sample relative to the whole of Scotland. As a result, the definition of a comparison group is somewhat arbitrary. Yet, it constitutes an arguably more valid counterfactual, as it is likely that nearby neighbourhoods share age and socio-demographic profiles and urban amenities, as opposed to more distant areas.

We start by running fully saturated regressions of confirmed COVID-19 cases at the daily level such as:

$$y_{ik,d} = \mu_{ik} + \tau_d + \sum_{d=224}^{D=387} \mu_{ik,d} \times \mathbb{1}(\text{Day} = d) + \beta' M_{l,d} + \gamma' X_{ik,m} + \varepsilon_{i,m} \quad (1)$$

where  $y_{ik,d}$  is the number of confirmed COVID-19 cases over the previous seven days per 100,000 population in date  $d$ , in the Intermediate Zone  $i$  within  $k$  kilometres from neighbourhoods containing student residences. The regression in (1) estimates dynamic treatment effects with two-way fixed effects: Intermediate Zone fixed effects  $\mu_{ik}$  in the comparison bandwidth distance  $k$ , as well as daily fixed effects,  $\tau_d$ . This dynamic differences-in-difference strategy include series of binary variables representing each date  $d$ , which represent the difference in COVID-19 cases in treatment locations vs control between a date  $d$  and the reference date 10th of August 2020. We select the 10th August 2020 as the reference date, a day where the number of cases was extremely low nationally. The data end on 22nd January 2021. As mentioned earlier, for confidentiality purposes, Public Health Scotland suppresses the reporting of cases where an Intermediate Zone has fewer than three cases. To mitigate this decision, we have re-coded all missing values as zero values. To attenuate potential measurement errors, every regression in (1) is also re-estimated using the inverse hyperbolic sine transformation of the number of cases.<sup>28</sup> It should be noted that there is a considerable difference if one focuses on the often-used natural logarithm, as the analysis would therefore only take into account locations that have seen a growth of cases in the last week.

One of the advantages of employing the dynamic local differences-in-differences approach described above is that it relaxes a single, homogeneous treatment effect assumption common for standard differences-in-difference estimators. It is implausible to believe that the treatment effect estimates would be constant over time given the rapidly changing situation, with restrictions to mitigate the spread of COVID-19 changing across regions and hardening over time as described in section 2.

The assumptions underlying a causal interpretation to our estimates are twofold. First, the Stable Unit Treatment Value Assumption (SUTVA), which states that there should be no spillovers of infection between student neighbourhoods and their comparison groups. This is naturally likely to be violated, and we tackle this head on in section 3.2. However, if there

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<sup>28</sup>A semi-elasticity can be obtained as normal by exponentiating the coefficient of interest (Bellemare and Wichman, 2020)

is some positive spillover, the estimates retrieved by our method will represent a lower-bound estimate. Second, it is the presence of counterfactual parallel trends, which states that in the absence of students moving into student halls the average rate of infection in student neighbourhoods would be the same as in those adjacent neighbourhoods. To explore the validity of this assumption we begin our analysis on 10th of August 2020, a full month before students were due back at University, and pre-dating the resumption of face to face primary teaching.

The empirical design adopted aims at estimating causal effects by comparing nearest neighbourhoods, hereby attenuating the potential bias originating from systematic differences across areas. For this reason, this approach can also be thought of as a linear differences-in-discontinuities with a fixed bandwidth of  $k$  kilometers (Grembi et al., 2016). One concern is that there may still be differences at baseline between neighbourhoods. Although these differences should be net out by the neighbourhood fixed effects, we cannot rule out that these differences may reflect different baseline propensities for infection due to the correlation between cases and underlying socio-demographic characteristics. To address these concerns a number of control variables are included in every model.  $X$  is a matrix containing a number of variables at neighbourhood level, such as the proportion of people aged 50+, and measures of overcrowded housing and disability rates from the Scottish Indices of Multiple Deprivation. It should be noted that these variables are not in of themselves time-varying but are allowed to affect the outcome at month level  $m$  by interacting them with a monthly time trend as in Feigenbaum and Muller (2016). Finally, we also include data on public transport mobility at local authority level  $l$  on a weekly basis  $w$ , which are compiled and controlled for in matrix  $M$ . A more detailed description of these control variables is offered below.

Two-way fixed effects specifications such as (1) may raise additional concerns. There is a novel and growing literature that highlights potential for bias stemming from differential treatment timing. As mentioned in the section 2, the start of the autumn term (i.e., treatment timing) varies for each university, and hence treatment neighborhoods (see for example: Goodman-Bacon, 2018; Callaway and Sant’Anna, 2020; Sun and Abraham, 2020; Roth and Sant’Anna, 2021). There is a panoply of competing estimators being proposed to address the bias, nevertheless, the underlying issue is that the two-ways fixed effects provides a weighted estimator that averages over all the estimates. At times this may average over periods that may not be appropriate comparison units, and this may lead to biased estimates of the true dynamic treatment effect. In order to avoid this pitfall, the approach we adopt here is to apply the same regression as (1) but do this over the  $g$  subsamples of term start dates. In other words, we will control for potential contamination of control groups by running separate event study according to the term start date. As before, the control units considered here are always neighbourhoods which do not have student halls which are drawn from a radius of  $k$  kilometres from the central point of a student neighbourhood. This approach

has the advantage to eliminate the biased warned by the growing differences-in-differences literature, while at the same time it is easy to interpret. As further robustness, we implement the doubly robust estimator of Callaway and Sant’Anna (2020). The results from this latter exercise are presented in section 4.1. Note that in the Callaway and Sant’Anna we opt for using later treated groups as the comparator group, losing out the final group of starters to the estimation procedure.

**Control variables** The present analysis controls for the matrices  $X$  and  $M$ . The contents of these matrices are as follows: The  $X$  matrix is derived from the 2019 Scottish Indices of Multiple Deprivation (SIMD) (Scottish Government, 2019). The SIMD are sub-neighbourhood statistics that are released at Data zone resolution. Recall that Intermediate Zones nest multiple data zones, which in turn are all nested in local authority districts.<sup>29</sup> As the data are more finely grained than the analysis presented here, it was necessary to aggregate these up to Intermediate Zones. The population weighted average of each SIMD measure was computed for each Intermediate Zone using the latest 2019 population estimates. The specific subcomponents of the SIMD that are used are the comparative illness factor (CIF) and the overcrowding rate. The CIF is a standardised ratio of the number of claimants of a number of government illness and disability benefits.<sup>30</sup> The overcrowding rate is the proportion of households in a given area that live in overcrowded housing based on an occupancy rating. The occupancy rating compares the actual number of rooms in the house to the number of rooms which are required by the household, based on the relationships between them and their ages.<sup>31</sup> Both of these factors were chosen as they account for some important underlying differences at baseline, namely the underlying health of the local population, and the suitability of their housing. We also have controls that account for differential socio-demographic makeup on neighbourhoods. We utilise data from the 2019 population estimates at neighbourhood level to estimate the proportion of population in a neighbourhood that is over 50.

The  $M$  matrix utilises data from the community mobility reports from (Google LLC, 2021). These data are derived from mobile phone user data using Google Maps. The data are released at daily level, and for Scotland these are released at Local Authority District level. For each district, the data represent the percentage deviation in visits to a certain amenity relative to the median response for the same day of the week in 03/01/2020-06/02/2020. The data are released for a number of amenities including transport, supermarkets, parks, retail, workplaces and residential. It should be noted that for some district-amenity combinations

<sup>29</sup>That is there is no Intermediate Zones or data zones that cross administrative borders.

<sup>30</sup>This is comprised of Disability Living Allowance, Attendance Allowance, Incapacity Benefit (not receiving DLA), Employment and Support Allowance, Severe Disablement Allowance, Income Support with disability premium, Personal Independence Payment and Universal Credit claimants with an accepted restricted ability to work. (Scottish Government, 2020)

<sup>31</sup>An occupancy rating of -1 or less indicates overcrowding. This means that there is at least one room too few in the household. For more information see <https://www.gov.scot/publications/simd-2020-technical-notes/>

due to privacy restrictions wherein the data do not meet the either the data quality or privacy threshold, the data are suppressed by Google. This means that these should be treated as true unknown data, that is one cannot infer there is a lack of movement due to the lack of data in a given combination. Unfortunately for the present analysis, the residential category in various Scottish districts falls afoul of this restriction, which means that using this as a control would restrict the analysis. For this reason, we have opted to only focus on the public transport amenity, as this is often, not missing, and will indicate the variation of movement into, within and out of a given local authority area.

### 3.2 Spillover Analysis

This section expands the empirical strategy with the specific purpose of tackling the second research question: Can the spillover to the neighbouring areas be measured? What is the effect of living in an neighbourhood adjacent to a student one?

It is plausible that if the infection reproduction rate is above 1 in areas containing student halls, people living in surrounding neighbourhoods are more likely to become infected as their chance of encountering the virus increases. This chance may contaminate the comparison group used in the previous analysis. This concern is similar to that encountered in the RDD literature in relation to heaping or discontinuous density to the border of the RDD. One often-used robustness check follows from [Barreca et al. \(2011\)](#) who propose to do a ‘donut’ RDD; where one drops the potentially problematic centre of the donut, and the RDD is run over the the remaining whole. [Eggers et al. \(2018\)](#) extend this approach and suggest that a donut-differences-in-discontinuities approach may mitigate the issue of sorting around the threshold of the discontinuity.

We have sought to motivate the regression analysis presented here as a ‘local differences-in-differences’ approach, that is the distance to the nearest treated hall is not a covariate in the control matrix of the regression. However, one can extend the present analysis to incorporate the donut approach to estimate the spillover effects of COVID-19 from the neighbourhoods of their halls to their neighbours, and their neighbours-neighbour’s.

This approach can be extended to the present analysis. The donut hole, is therefore the neighbourhood that contains one or more student halls of residence. The inner donut, or the group to be investigated, are those whom are within  $k$  kilometres from the nearest hall, and who previously acted as a comparison group. Whilst the outer donut are those units which are within  $2k$  kilometres of the student halls. So for example, in the 1km donut, the inner donut is those neighbourhoods within 0-1km of the student halls (excluding the student halls neighbourhood), and the outer donut are those between 1-2km of the student halls. The spillover analysis therefore follows on from the main analysis suggesting that the best comparison groups are those which are nearest to the potential spillover zones. In the present analysis we will investigate donuts that range from 1km to 5km, comparing their nearest and



respective 1-5kms.

## 4 Results

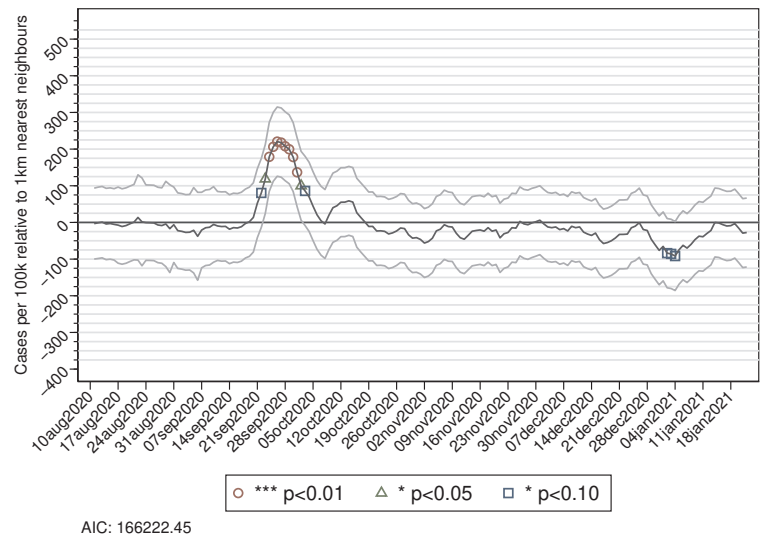
### 4.1 Baseline Analysis

We start by presenting results from the analysis using the functional form outlined in 1, which includes all the control variables described in the previous section, and thus accounts for differential trends in transport mobility within local authority districts, and allows for underlying demographic and health differences to have differential effects on outcomes. Figures 3 and 4 present the estimates of the new daily confirmed COVID-19 cases relative to the surrounding (comparison group) areas. For robustness purposes, the definition of the comparison group area changes by varying the distance to the area containing student halls, from 1km to 5km. These estimates reveal a wave of COVID-19 within student's halls areas compared to the nearest areas, with infections rising approximately to 100 cases per day per 100,000 on 21st September and doubling one week later at above 200. The number of cases declines quickly and are found to be not statistically different from the neighbourhood areas approximately on 5th October. The evolution of infections seem to have responded to the new Government restrictions and bans imposed on students by Universities on 22nd and 23rd September (See 2). This first spike in cases is immediately followed by a minor second spike, which is detected in every model. Still, it is statistically significant only when compared to areas within 3 and 4 km from halls. This second wave has a peak of 50 cases per day per 100,000 and lasts for less than two weeks. The remaining of the period is characterised by a number of cases that is not different from the surrounding areas. If anything, some models reveal fewer infections than the adjacent areas in two instances: from the second part of October to mid-November, and at the end of December-beginning of January. The fewer cases may be driven by the fact that students were given the possibility to return home after October and others left halls for the Christmas holidays.

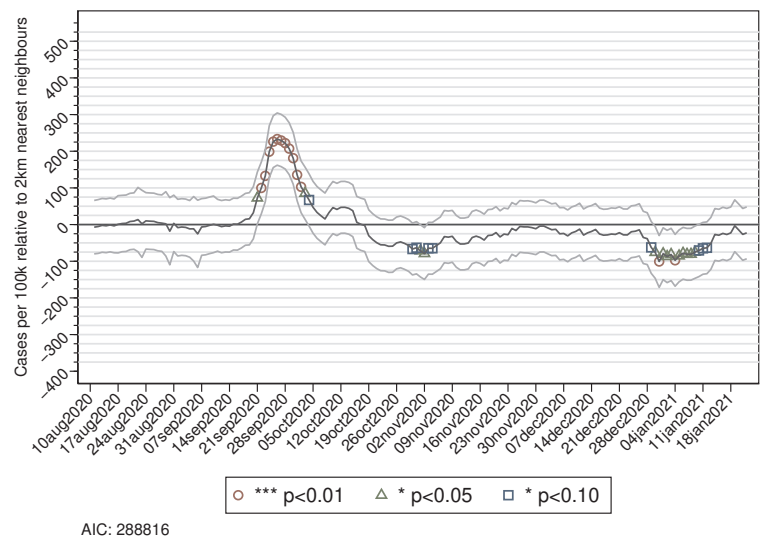
**TWFE Heterogenous Treatment timing** A major concern is that due to the staggered start to the autumn Semester across Scottish universities there could be substantial heterogeneity in effects in response to the shifting public health policy mitigations introduced by the Scottish Government. As such, the effect of being a neighbourhood that contains halls for university that started classes in the first week of September 2020 on cases is likely to be very different than that for those in the first week of October. This section speaks to this concern by running models using a TWFE estimator to obtain estimates of the increases in daily cases in locations with halls relative to contiguous areas by semester date. For ease of exposition we plot estimates from models using areas within 1 km as comparison groups. in Figures 5 and 6. These estimates reveal the presence of substantial heterogeneity. Note

**Figure 3:** Daily cases in areas with halls relative to adjacent areas, COVID-19 cases per 100k

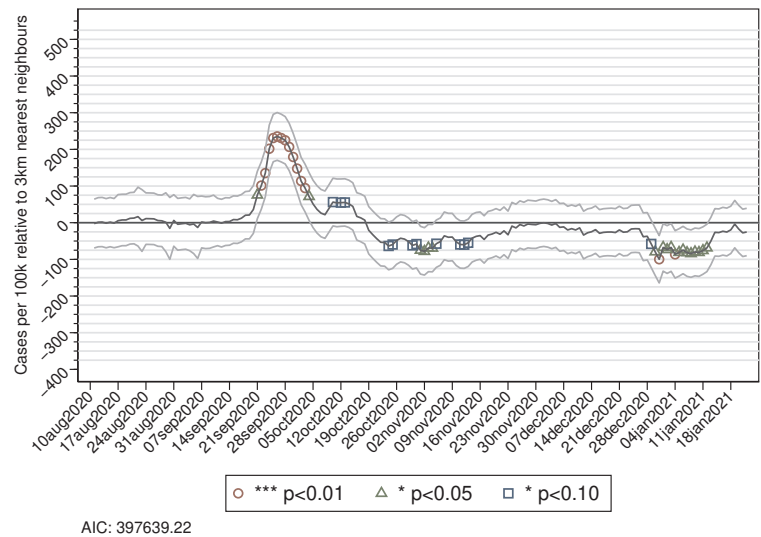
(a) Comparison group within 1km of halls



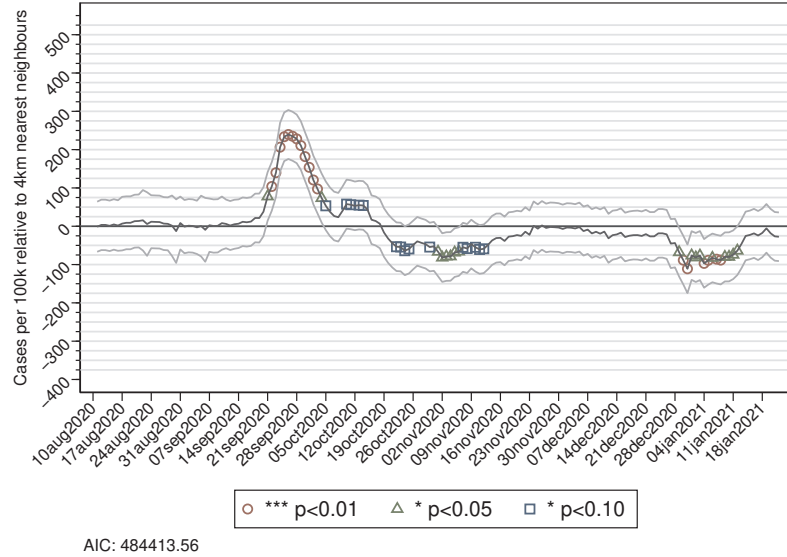
(b) Comparison group within 2km of halls



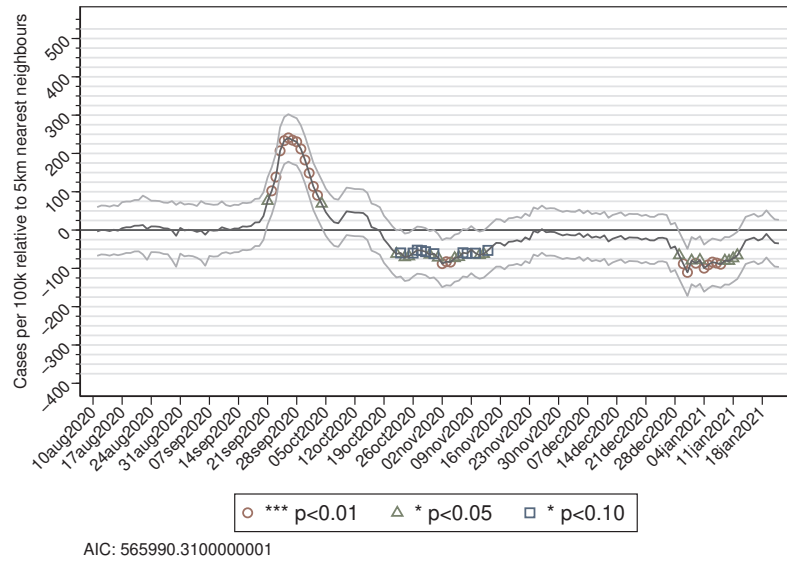
(c) Comparison group within 3km of halls



(d) Comparison group within 4km of halls



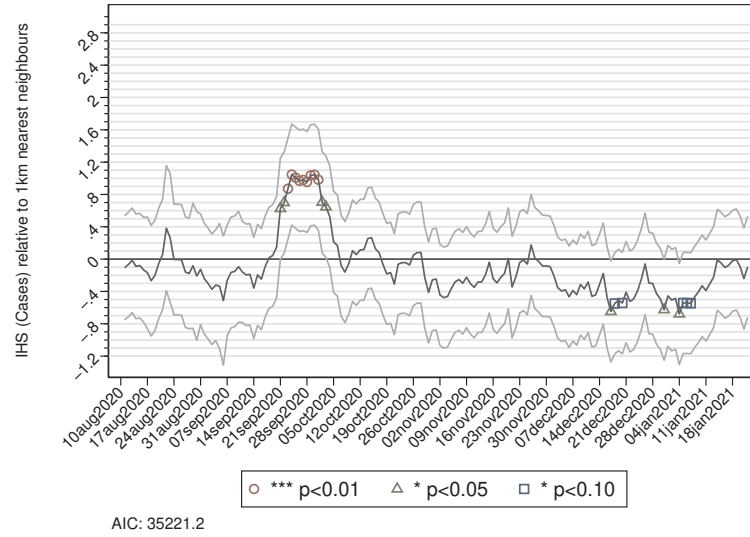
(e) Comparison group within 5km of halls



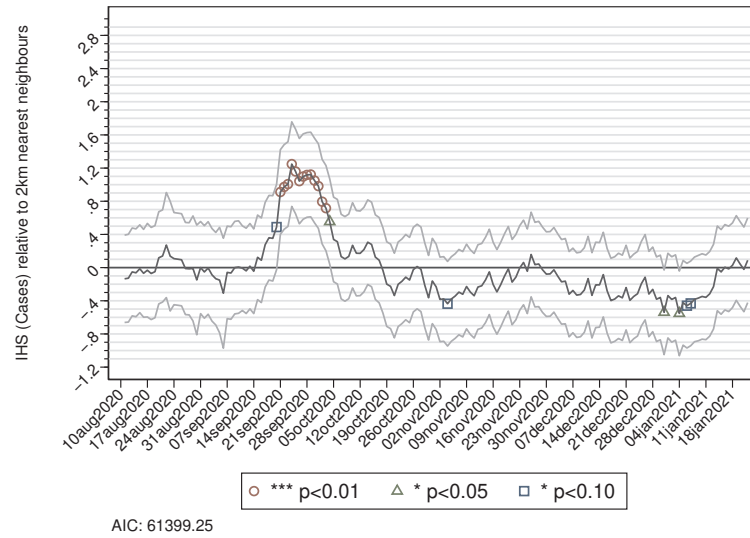
NOTE: Figures report the difference in daily COVID-19 cases between contiguous areas using (1). Each plot shows standard significance levels through different markers. Note each subfigure alters the comparison group for the treatment group where the comparison groups are drawn within  $k$ km of a student halls neighbourhood. Confidence intervals from neighbourhood halls and month clustered standard errors are plotted. All regressions estimated here use the full battery of controls. Mobility: Daily Transport usage relative to January 2020. Health: Allowed to vary at monthly level, Comparative illness factor and housing overcrowding. Age: Effect allowed to vary monthly, proportion of over 50s living in neighbourhood. Note that due to data restrictions the mobility data do not cover all time periods, thus any temporary losses should be considered missing at random.

**Figure 4:** Daily cases in areas with halls relative to adjacent areas, inverse hyperbolic sine of COVID-19 cases

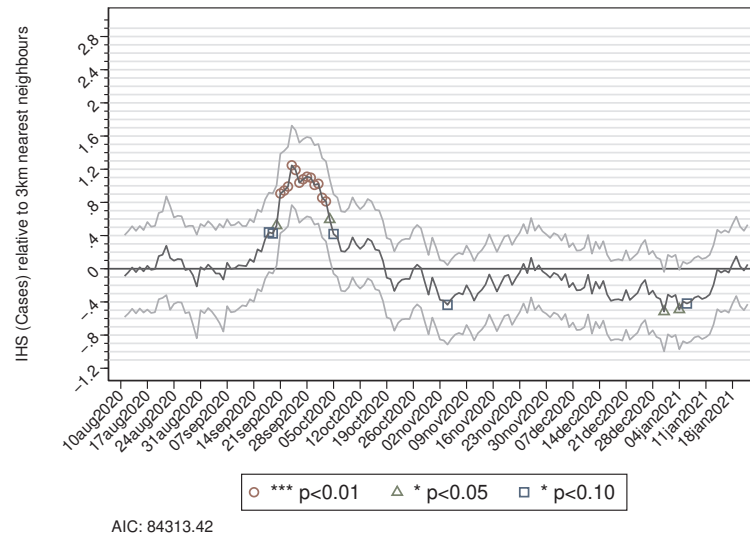
(a) Comparison group within 1km of halls



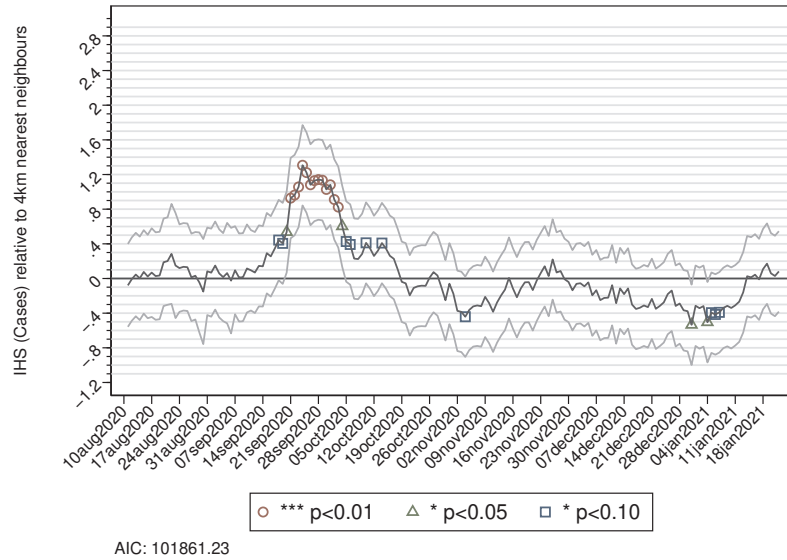
(b) Comparison group within 2km of halls



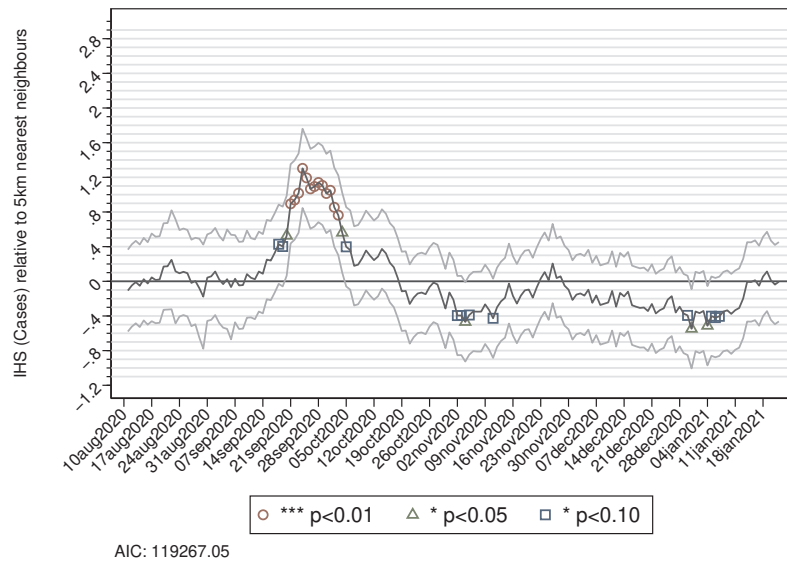
(c) Comparison group within 3km of halls



(d) Comparison group within 4km of halls



(e) Comparison group within 5km of halls



NOTE: Figures report the difference in daily COVID-19 cases between contiguous areas using (1). Each plot shows standard significance levels through different markers. Note each subfigure alters the comparison group for the treatment group where the comparison groups are drawn within  $k$ km of a student halls neighbourhood. Confidence intervals from Neighbourhood Halls Cluster and Month clustered standard errors are plotted. All regressions estimated here use the full battery of controls. Mobility: Daily Transport usage relative to January 2020. Health: Allowed to vary at monthly level, Comparative illness factor and housing overcrowding. Age: Effect allowed to vary monthly, proportion of over 50s living in neighbourhood. Note that due to data restrictions the mobility data do not cover all time periods, thus any temporary losses should be considered missing at random.

that the findings do not change as the presence of heterogeneity is evident regardless of the composition of the comparison group. The main spike in cases visible in the normal TWFE estimates is mainly driven by the cluster of student halls whose universities began on 14th September 2020. For those neighbourhoods containing halls whose universities began in the second week of September the rate of COVID-19 cases rises by the 21st of September initially by an additional 100 cases per 100,000 relative to their 1km nearest neighbours, and eventually peaks at an additional 400 cases per 100,000 per day on the week of 28th September from which it declines until 19th October, when the raft of new measures introduced on 25th September begin to have an effect. The number of cases settle at what appears to be a new equilibrium running at approximately 100 additional cases per 100,000 per day relative to their neighbours until the end of November. Conversely for universities beginning on 9th September the peak from their start of semester is never significantly higher than their neighbours, and quickly tails off until it sees a second wave in late November that peaks with an additional 350 cases per 100,000 relative to their neighbours that is contained by the start of December. For the universities that began their semester on 21st of September there is a significant increase in the number of cases one week after their start of semester, though again at its peak it does not exceed an excess of 250 cases per 100,000 per day relative to their neighbours, the effect dissipates, and then abruptly peaks a second time on the week of 12th October, only to dissipate again. Finally, for Universities beginning 5th October, these neighbourhoods were running significantly fewer cases in the lead up to the start of their semester, and these locations, though they do see a rise in cases, they trend with fewer cases than their neighbours, until January 2021. However, given that only two universities started on October 5th, and one is a campus based university, whilst the other is an urban based university, caution must be adopted in interpreting these results.

When looking at the inverse hyperbolic sine results presented in Figure 6, the increase in cases is notable in areas where universities began on 14th September we find this to be 230% of cases relative to the nearest 1km neighbours on the 14th of September, and rising to a peak of 847% on 6th October. It is worth noting that though cases seem to be following an upward trend ahead of 14th September, students were allowed to move into student halls two weeks ahead of the start of semester, this may in part explain the upwards trend evidenced ahead of the start of semester. This alternative specification picks up an earlier spike of case load in August, which starts to decline come the week of September 7th, before the start of semester on 14th September. We conjecture that this spike can be attributed to two things. First, schools in Scotland went back for in person teaching between 10th-17th August. It is not implausible to conjecture that there was some contagion from nearby clusters emerging from schools for the urban universities. Second, urban universities are located in areas with lots of amenities including restaurants. As documented by [Fetzer \(2020\)](#) the Eat Out to Help Out (EOHO) scheme, which subsidised restaurant meals to help the sector, led to an increased

number of cases. The programme run until the end of August. The fact that a decline in new cases can be seen one week after the conclusion of the EOHO scheme, indicates that may indeed have played a part in the higher than average case load, though it should be noted that in terms of spread of COVID-19 this EOHO induced spike is less than half of the increased cases caused by student migration at its peak.<sup>32</sup>

**Doubly Robust Estimation** TWFE is not the most efficient estimator in this instance. The Estimator developed by [Callaway and Sant’Anna \(2020\)](#) may yield better estimates. As an additional robustness check Figures 7 and 8 shows the heterogeneity by start dates as estimated by the [Callaway and Sant’Anna](#) estimator. The estimator reveals qualitative similar findings to the TWFE heterogenous treatment timing estimates presented earlier. But to summarise the previous discussion, there is considerable heterogeneity in the estimates of the student effect conditional on university start. The heterogeneity is due to the changes in COVID-19 restrictions which differed slightly across locations and became increasingly tighter across the whole of period between September and December. The changes in public policy obviously leave differential effects due to these policy changes.

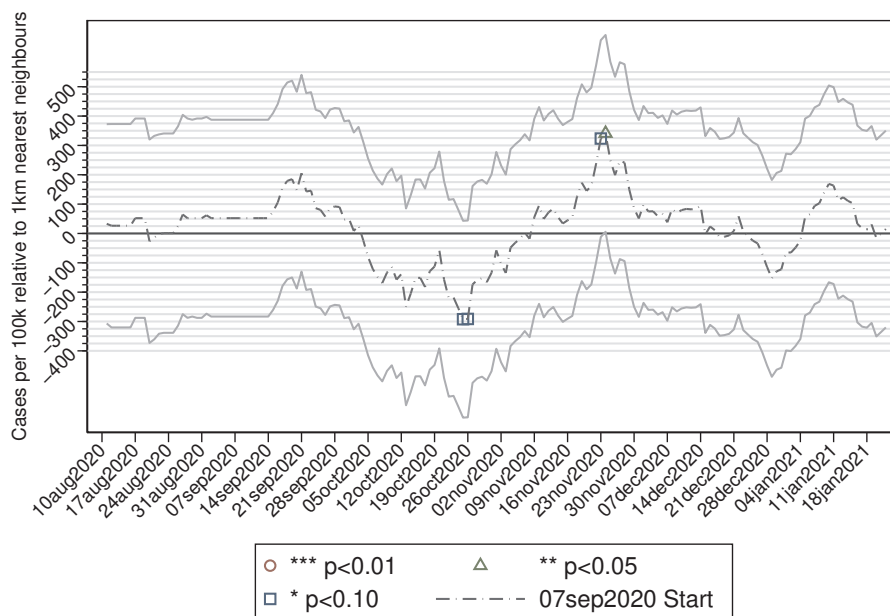
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<sup>32</sup>Note that though we find that EOHO accounts for less than half the number of cases as the student peak, it is not our intention to estimate the effects of this policy, but this is the incidental estimate insofar as the neighbourhoods we study are affected by the EOHO policy.



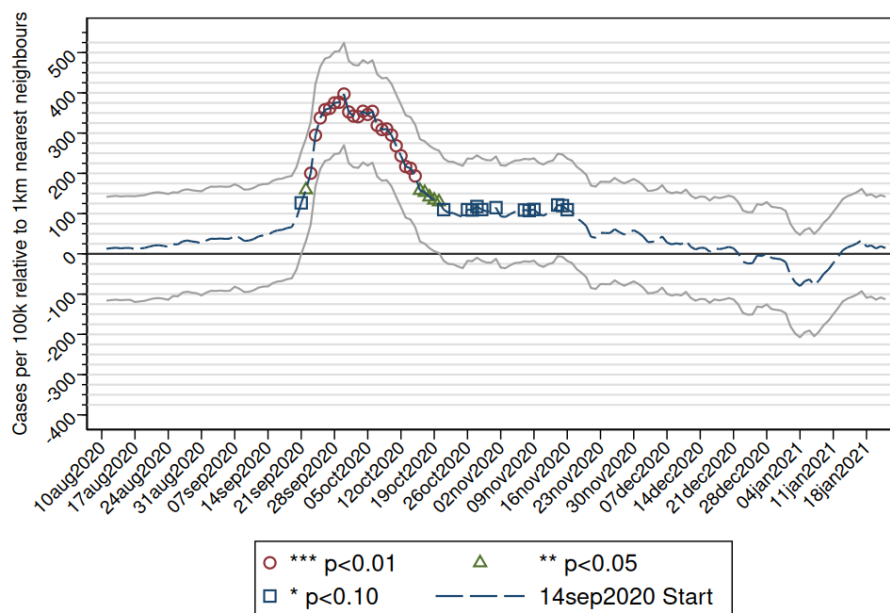
**Figure 5:** Daily cases in areas with halls relative to 1km nearest neighbours by semester start date, COVID-19 cases per 100k

(a) 07 September 2020 Semester Start



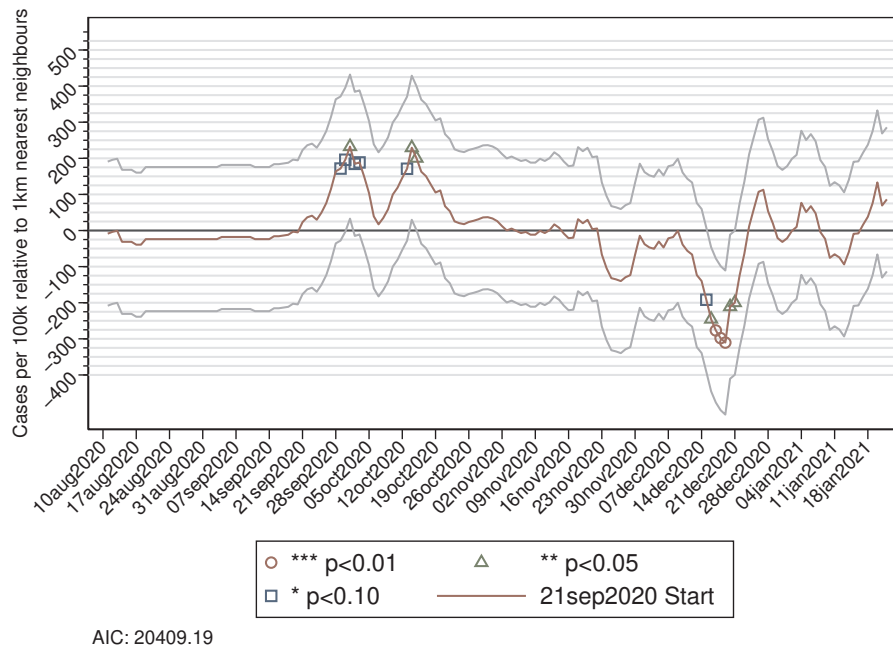
AIC: 14357.45

(b) 14 September 2020 Semester Start

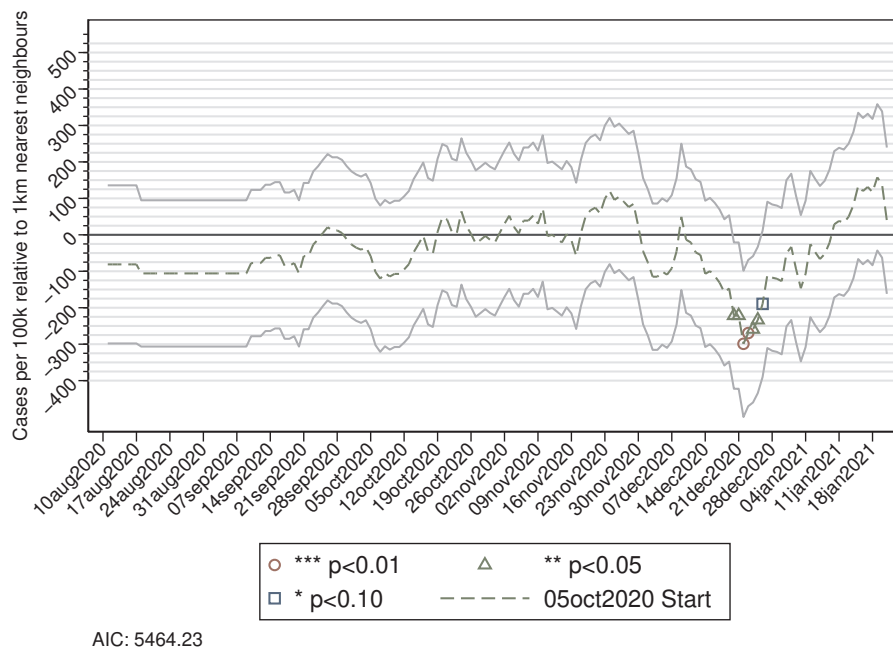


AIC: 139692.58

(c) 21 September 2020 Semester Start



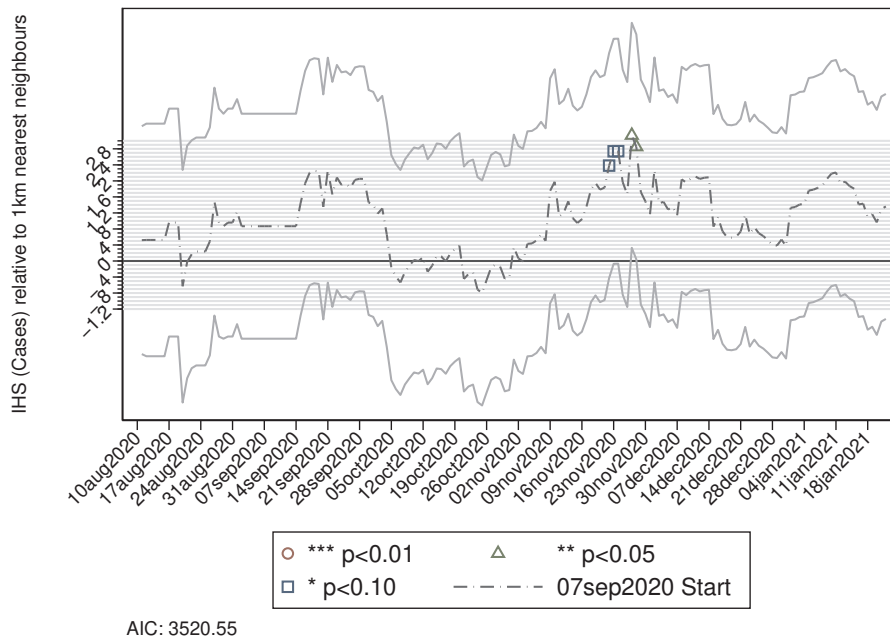
(d) 05 October 2020 Semester Start



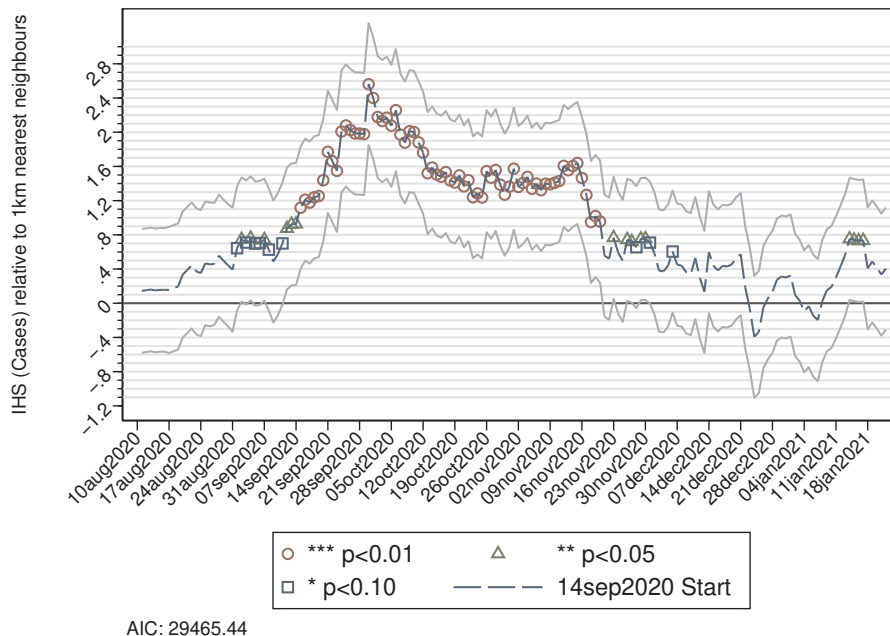
NOTE: Figures report the difference in daily COVID-19 cases between contiguous areas using (1). Each plot shows standard significance levels through different markers. Note each subfigure alters the comparison group for the treatment group where the comparison groups are drawn within  $k$ km of a student halls neighbourhood.

**Figure 6:** Daily cases in areas with halls relative to 1km nearest neighbours by semester start date, inverse hyperbolic sine of COVID-19 cases

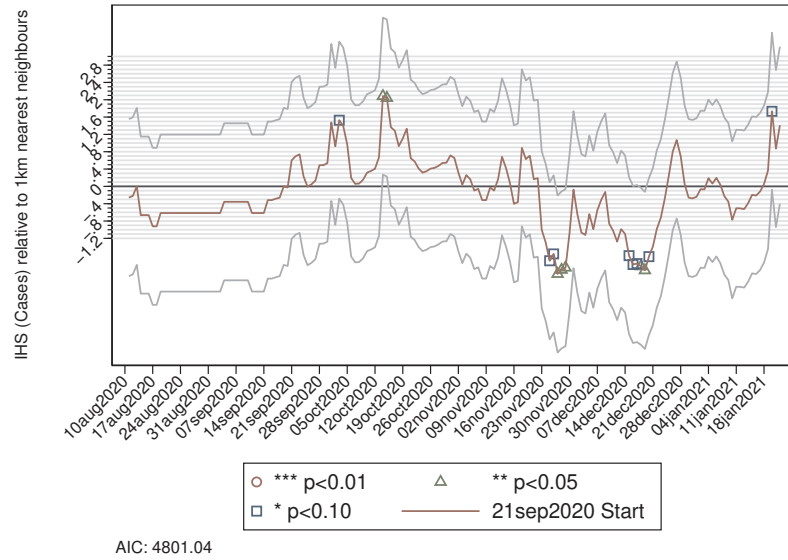
(a) 07 September 2020 Semester Start



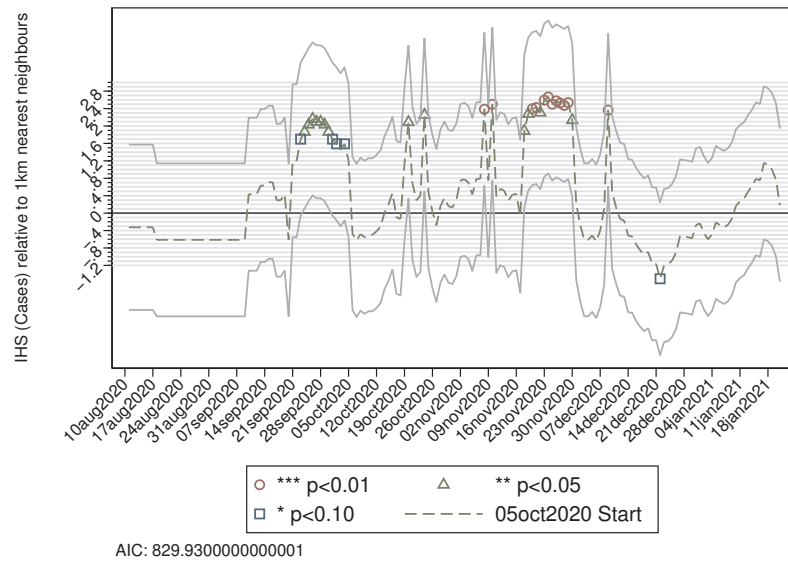
(b) 14 September 2020 Semester Start



(c) 21 September 2020 Semester Start



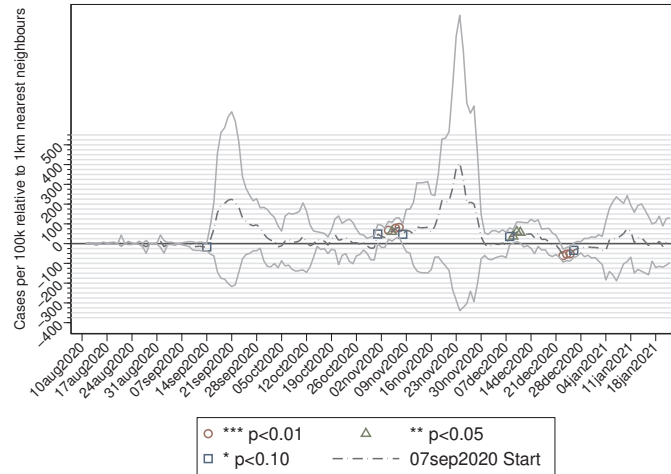
(d) 05 October 2020 Semester Start



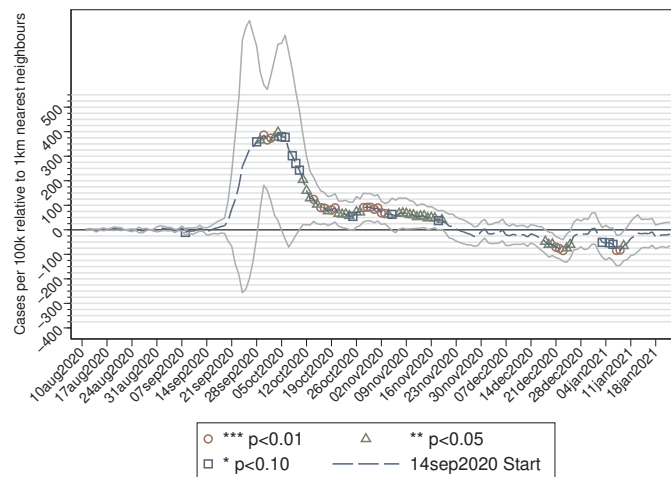
NOTE: Figures report the difference in daily COVID-19 cases between contiguous areas using (1). Each plot shows standard significance levels through different markers. Note each subfigure alters the comparison group for the treatment group where the comparison groups are drawn within  $k$ km of a student halls neighbourhood.

**Figure 7:** Doubly robust estimation of daily cases in areas with halls relative to areas within 1km using Callaway and Sant'Anna (2020), COVID-19 cases per 100k

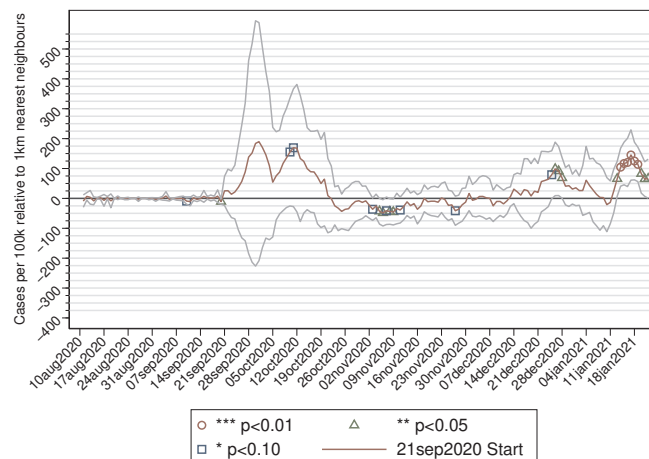
(a) 07 September 2020 Semester Start



(b) 14 September 2020 Semester Start



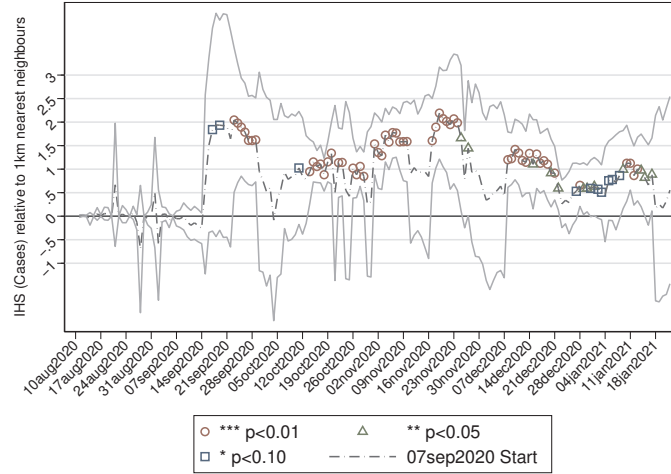
(c) 21 September 2020 Semester Start



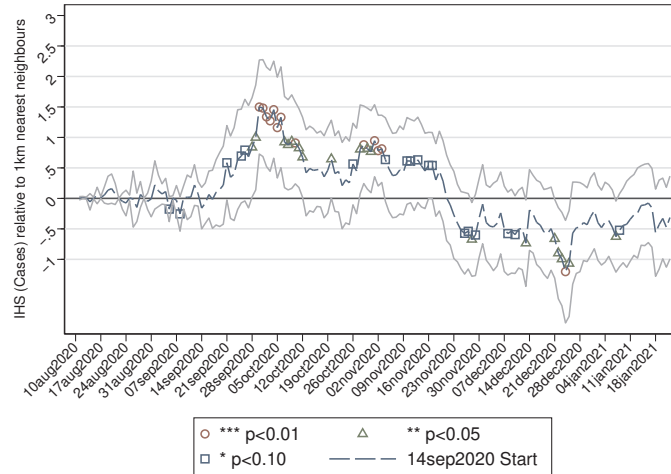
NOTE: Figures show estimates of daily cases in areas containing student halls compared to areas within 1km using the doubly robust estimator of Callaway and Sant'Anna (2020). The standard errors are bootstrapped. The estimates here are obtained using their R package `-did-` and Nick Huntington-Klein's `-att_gt-` wrapper for Stata (v.0.2.0).

**Figure 8:** Doubly robust estimation of daily cases in areas with halls relative to areas within 1km using Callaway and Sant'Anna (2020), inverse hyperbolic sine of COVID-19 cases

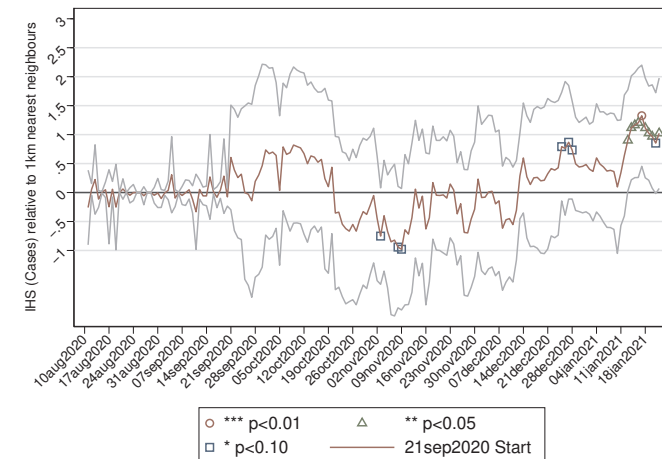
(a) 07 September 2020 Semester Start



(b) 14 September 2020 Semester Start



(c) 21 September 2020 Semester Start



NOTE: Figures show estimates of cases in areas containing student halls compared to areas within 1km using the doubly robust estimator of Callaway and Sant'Anna (2020). The standard errors are bootstrapped. The estimates here are obtained using their R package `-did-` and Nick Huntington-Klein's `-att_gt-` wrapper for Stata v0.2.0.

## 4.2 Spillover Analysis

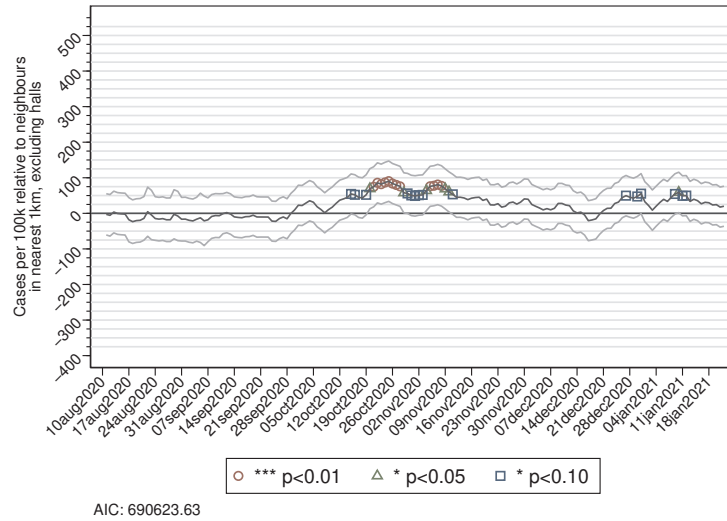
This section aims to answer the second research question about the potential spread of COVID-19 in areas more distant to halls. To answer this question, we will now turn to what we term the ‘donut’ analysis. This analysis excludes all neighbourhoods containing student halls. Instead, the estimation will focus on the cases in those areas that were utilised as a comparison group in the previous analysis (i.e., the nearest locations to those containing halls) relative to their surrounding areas, i.e., those that are further away from the student residences. In other words, their comparison group is drawn from the same  $k$  kilometre distance from the neighbourhoods adjacent to student halls. So, for example, the 1km donut compares those neighbourhoods within 0-1km of student halls and contrasts the impact with that of the neighbourhoods which are 2-3km from student halls. Similarly, the 5km donut compares neighbourhoods within 0-5km of student halls and contrasts them with those neighbourhoods 5-10kms from student halls.

The results from this analysis are plotted in Figures 9 and 10. The estimates suggest that regardless of which sized donut one picks there is a substantial increase in the number of cases in those neighbourhoods near student halls, relative to their adjacent neighbourhoods. The specification which minimises the AIC is that of the 3km donut where one compares the neighbourhoods 0-3kms to 4-6kms. The figures have been drawn in the same scale as the student halls’ analysis, to further contextualise the onwards transmission. Those locations nearest to student halls see an increase in cases approximately one week after the main impact was shown on 14th September. This lag is consistent with the literature showing that cases that finds 3-5 days for incubation and for symptoms to present as between 5-14 days after being exposed (Lauer et al., 2020; Qin et al., 2020; Chun et al., 2021). The increase in cases is approximately an additional 20-80 daily cases per 100,000, and persist until the end of November. The inverse hyperbolic sine results show a consistent story, where the increase in cases represents a 20-50% increase in cases between the inner and outer donut.

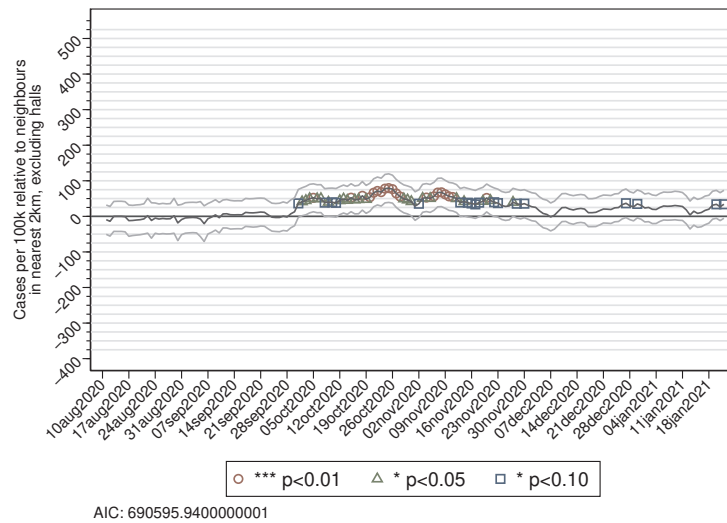


**Figure 9:** Estimates of impact of student halls on onward transmission, daily COVID-19 cases per 100,000

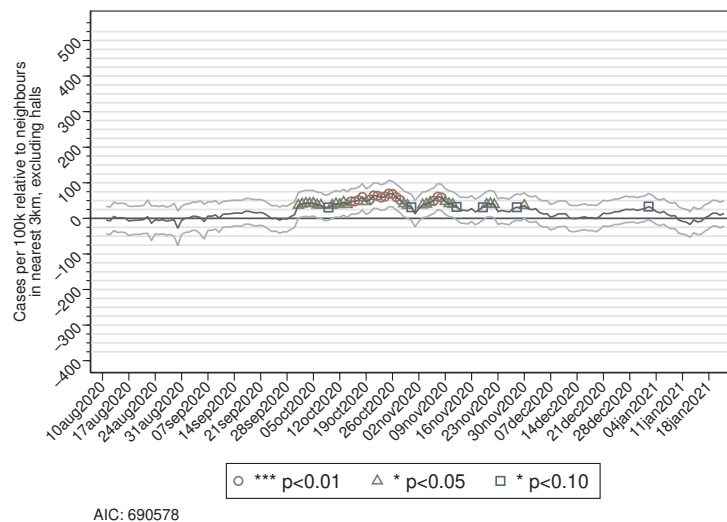
(a) 0-1km vs 2-3km of halls donut



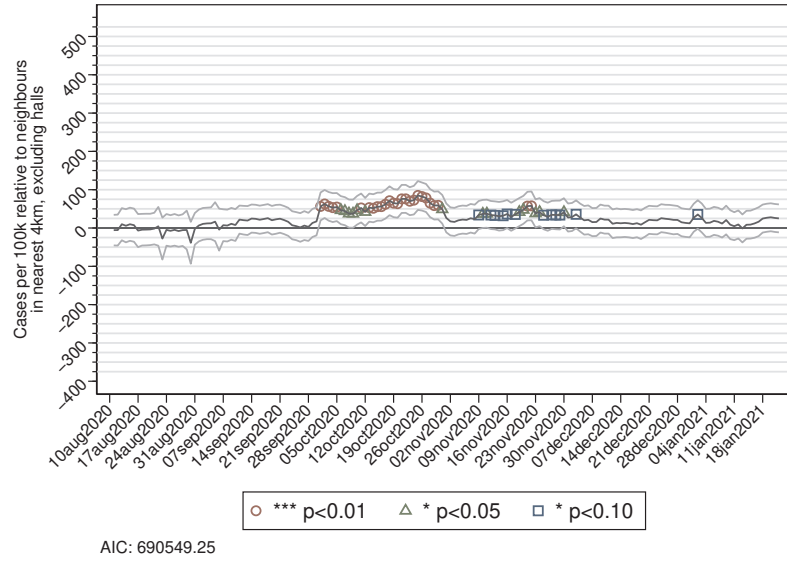
(b) 0-2km vs 3-5km of halls donut



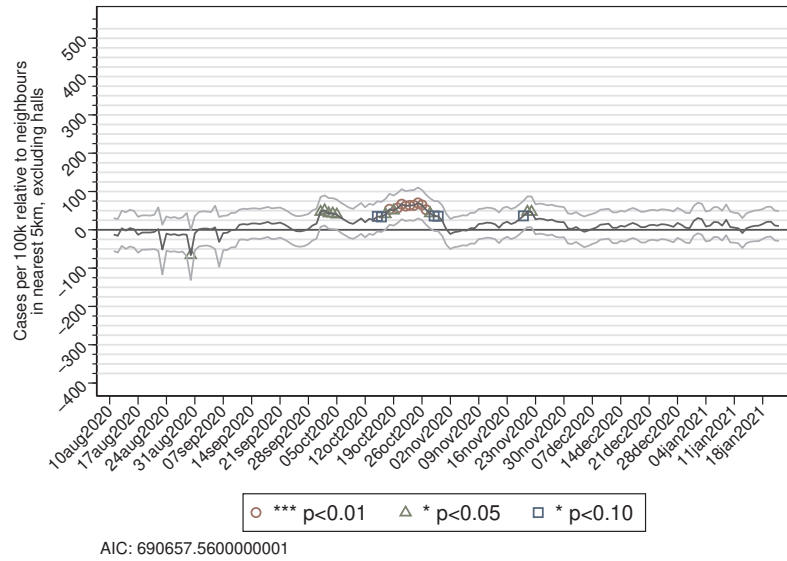
(c) 0-3km vs 4-6km of halls donut



(d) 0-4km donut vs 5-8km of halls donut



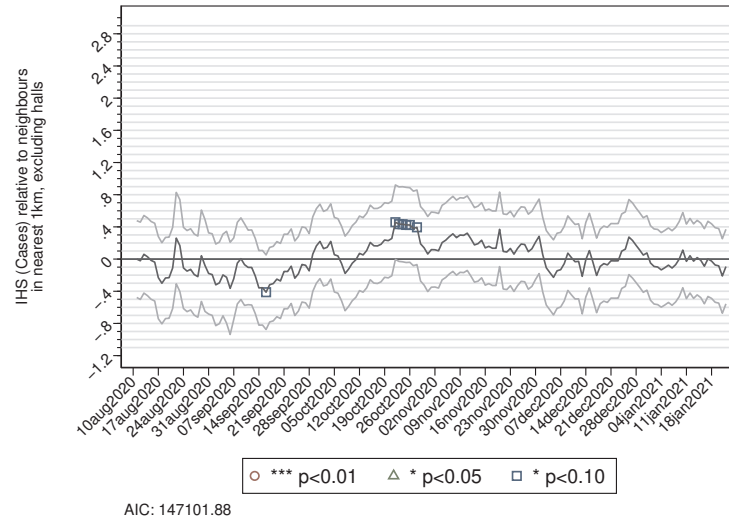
(e) 0-5km vs 6-10km of halls donut



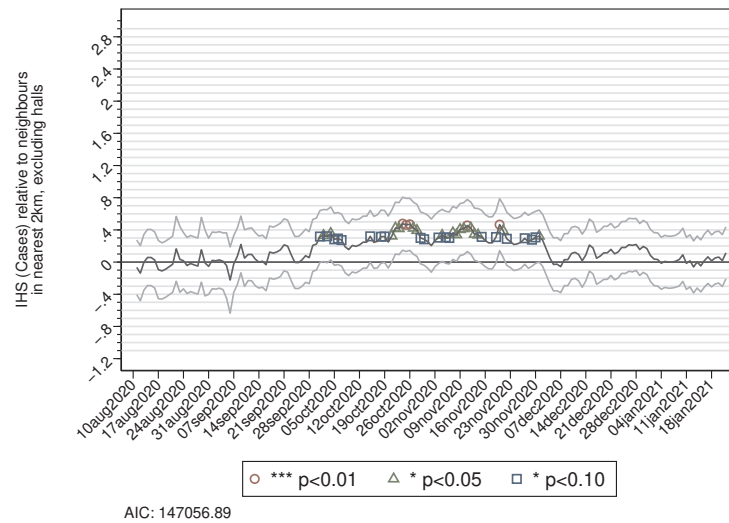
NOTE: Figures report the difference in daily COVID-19 cases between contiguous areas using (1). Each plot shows standard significance levels through different markers. Note each subfigure displays a different donut, such that one is excluding all student hall neighbourhoods, and impact on onward transmission is obtained by comparing those neighbourhoods with in  $k$  km to student halls are compared to the next  $k$  km. For example, the 1km donut compares 0-1km nearest neighbourhoods with those 2-3kms. Confidence intervals from Neighbourhood Donut Halls Cluster and Month clustered standard errors are plotted. All regressions estimated here use the full battery of controls. Mobility: Daily Transport usage relative to January 2020. Health: Allowed to vary at monthly level, Comparative illness factor and housing overcrowding. Age: Effect allowed to vary monthly, proportion of over 50s living in neighbourhood. Note that due to data restrictions the mobility data do not cover all time periods, thus any temporary losses should be considered missing at random.

**Figure 10:** Estimates of impact of student halls on onward transmission, inverse hyperbolic sine of daily COVID-19 cases per 100,000

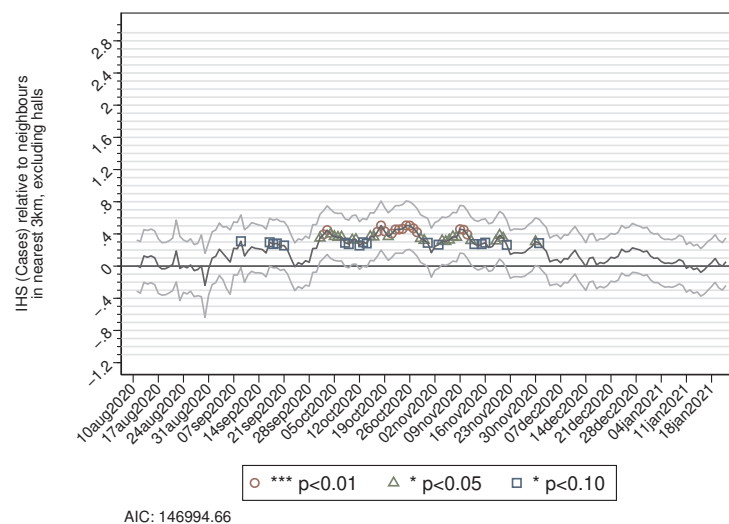
(a) 0-1km vs 2-3km of halls donut



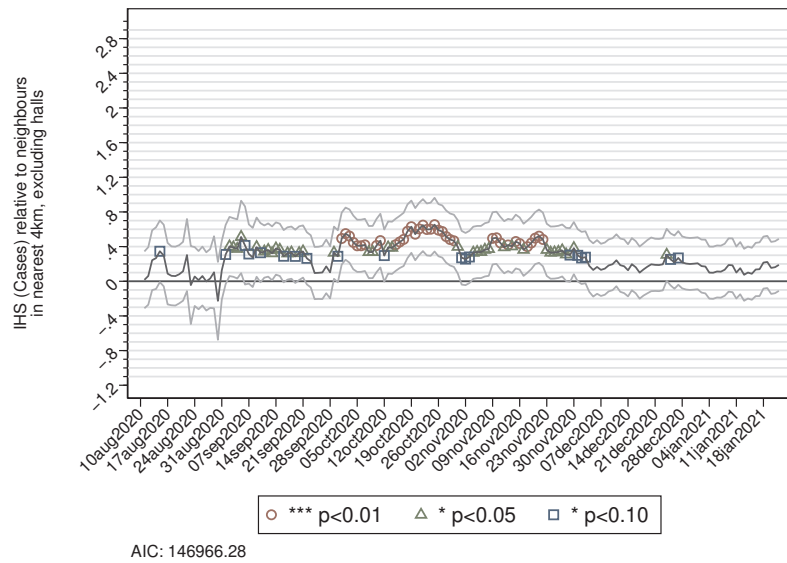
(b) 0-2km vs 3-5km of halls donut



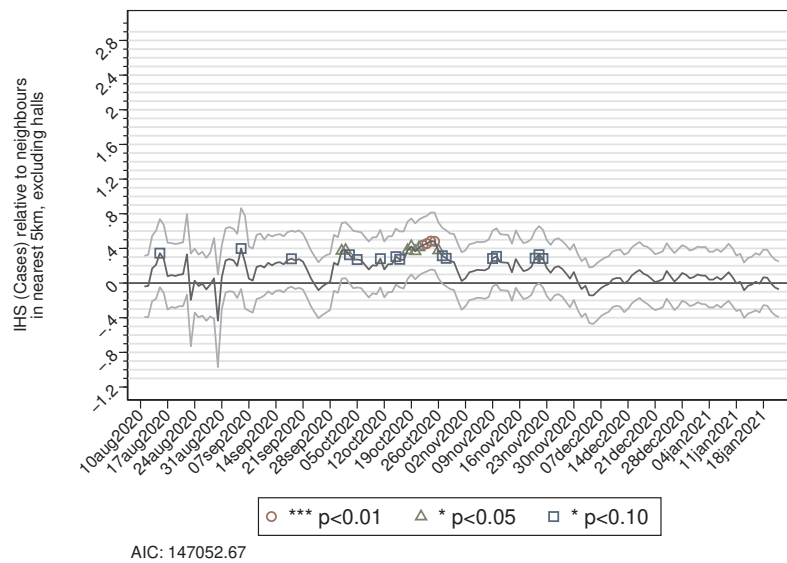
(c) 0-3km vs 4-6km of halls donut



(d) 0-4km donut vs 5-8km of halls donut



(e) 0-5km vs 6-10km of halls donut



NOTE: Figures report the difference in daily COVID-19 cases between contiguous areas using (1). Each plot shows standard significance levels through different markers. Note each subfigure displays a different donut, such that one is excluding all student hall neighbourhoods, and impact on onward transmission is obtained by comparing those neighbourhoods with in  $k$  km to student halls are compared to the next  $k$  km. For example, the 1km donut compares 0-1km nearest neighbourhoods with those 2-3kms. Confidence intervals from Neighbourhood Donut Halls Cluster and Month clustered standard errors are plotted. All regressions estimated here use the full battery of controls. Mobility: Daily Transport usage relative to January 2020. Health: Allowed to vary at monthly level, Comparative illness factor and housing overcrowding. Age: Effect allowed to vary monthly, proportion of over 50s living in neighbourhood. Note that due to data restrictions the mobility data do not cover all time periods, thus any temporary losses should be considered missing at random.

## 5 Conclusions

This paper investigated the effect of Scottish University reopenings in September/October 2020 on COVID-19 transmission in the areas surrounding student halls of residence.

We created a dataset that merges information on the geolocation of student halls with data on daily COVID-19 cases at neighbourhood (Intermediate Zone) level from August 2020 to January 2021.

The empirical strategy followed a local dynamic difference-in-difference or event study design. The analysis estimated the difference in daily cases between adjacent areas for each day from 10th August 2020 to 22nd January 2021. Contiguous areas are more likely to be statistically similar, and our models included day and neighbourhood fixed effects. Nevertheless, we also control for baseline differences in socio-demographic and health characteristics at the neighbourhood level and public transport mobility at the local authority level.

First, we estimated the increase in daily cases in those Intermediate Zones where halls are located relative to their neighbouring areas, i.e., areas within  $k$  kilometres from student residences. Second, we focused our attention on estimating the spillover effects with a ‘donut’ analysis. The ‘donut’ analysis had the objective of detecting the potential transmission from halls to neighbouring areas. This analysis excluded areas where residences are located (the hole of the donut), and instead compare the daily cases in areas immediately adjacent to halls (inner ring of the donut) with their neighbouring areas (outer ring). This second strategy has the advantage to address also a potential concern of violation of the SUTVA arising from the first analysis.

We plan to expand the current study to capture hospital admissions, ambulance calls, and mortality. However, the extent and timing of the local transmission represents a crucial step to understand how to respond to outbreaks.

We found a substantial and persistent increase in cases in areas containing halls and evidence of persistent spillovers, i.e., transmissions to the wider community in areas contiguous to halls. These effects are linked to the return of students at the start of the academic year, especially for a group of Universities that started on 14th September. These groups include large Universities located in the major urban areas. The cases began to rise on 21st September, with 100 extra cases per 100,000 of the population, and peaked a week later with 400 per 100,000, after which they started declining. However, the number of cases remained stubbornly higher relative to their contiguous areas until the end of November, recording an additional 100 cases per 100,000 per day. These estimates represent a lower bound as they are compared to contiguous areas that also experienced a persistent increase in cases relative to their neighbours following University reopenings. For these neighbourhoods, daily cases went up by an additional 20-80 cases per 100,000 until the end of November.

Our analysis suggests that student in migration into halls represented a risk for areas hosting the halls their surroundings, despite the pre-existing national restrictions on household

mixing and indoor gathering, and Universities mitigation with class-size limits, physical distancing rules in common areas, and enhanced hygiene measures. Noting that in the vast majority of cases there was no in person teaching over Autumn 2020. The findings broadly invite a re-think of how close proximity activity in Universities can be resumed, as the pre-existing mitigations barring severe curtailment of trading activity were not successful in keeping the spread in check. Looking further ahead it behooves policymakers to consider if the existing guidelines in combination with the vaccine roll out is sufficient to prevent future outbreaks.

Our findings confirm that more stringent containment measures introduced by the Government and Universities in the second half of September served to flatten the curve. However, these restrictions have been extremely costly from society's point of view.

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## A Key Dates and Coronavirus containment Measures

**Table A1:** Key measures in summer/autumn 2020 in Scotland

Date	Restriction
10 Aug 2020	The UK Government Coronavirus Bill and Second Coronavirus (Scotland) Bill were in place and Scotland were in phase 3 of the route map out of lockdown thus many restrictions were relaxed. Pubs, cinemas and restaurants were open and some non-contact sports and leisure activities were allowed. Social distancing rules of a 2m physical distance were in place indoors, outside and on public transport (unless seated at a restaurant). Mixing in private residences was banned and face coverings were compulsory in most public indoor settings; there were exceptions including mixing to care for vulnerable persons and those with physical or mental impairments or disabilities were not required to wear a mask. Two households totalling 8 individuals could meet outside at a 2m distance. Work from home for non-essential work was mandatory. Schools and nurseries were closed. Universities were closed for teaching and it had been announced that colleges and universities should make plans for a phased return to campuses in the upcoming academic year. Those suspected to have or have come in contact with someone with the virus had to self-isolate. Life events such as weddings and funerals were permitted with limited attendees. Aberdeen was under local lockdown. The Eat Out to Help Out programme to encourage people to go to restaurants had been implemented.
11 Aug 2020	Schools reopened with most face-to-face teaching back by 18th August.
14 Aug 2020	New legislation introduced for the hospitality industry, including Track and Trace.
28 Aug 2020	Increased restrictions surrounding social gatherings, large house parties indoors became a criminal offence.
31 Aug 2020	The last day of Eat Out To Help Out.
1 Sept 2020	Local restrictions in East Renfrewshire, Glasgow and West Dunbartonshire.
11 Sept 2020	Local restrictions extended to North and South Lanarkshire. The Scottish Government limited indoor and outdoor gatherings to six people from two households.
23 Sept 2020	Introduction of a national curfew for pubs, bars and restaurants and new restrictions on household visits.
23 Sept 2020	Universities ask students to avoid socialising outdoor during the weekend.
7 Oct 2020	Hospitality opening times restricted to 6am-6pm indoors, the sale of alcohol was prohibited. Licensed premises in the Central Belt required to close, with only takeaway services allowed. Outdoor live events, adult contact sports, indoor exercise classes were banned and snooker/pool halls, indoor bowling, casinos and bingo halls closed.
2 Nov 2020	Local authority protection measures were enforced through the Five-level Strategic Framework, each level indicating the level of protection needed based on the transmission of the virus in each local authority.
17 Nov 2020	Protection levels were updated, restricting travel outside of local authorities in Level 3 or Level 4 areas except for essential purposes.
8 Dec 2020	The first vaccines were distributed to those administering vaccines.
11 Dec 2020	Self-isolation period for positive contacts and overseas travel reduced from 14 days to 10 days.
25 Dec 2020	Restrictions eased for Christmas Day, allowing a maximum of three households to meet without observing social distancing and travel between the four nations.
26 Dec 2020	All of Scotland placed under level 4 restrictions; non-essential retail and hospitality closed and travel between Scotland and the rest of the UK prohibited, specific exceptions apply.
5 Jan 2021	Mainland Scotland entered lockdown, individuals had to stay at home except for essential purposes.
8 Jan 2021	The Scottish Government announced that University students must be taught online throughout January and February, unless ‘attendance is critical and time-sensitive to the course or assessment’, or due to essential placement or student well-being.
16 Jan 2021	Lockdown restrictions tightened, including prohibiting non-essential click and collect in level 4 areas and restrictions on the consumption of alcohol in public places.
15 Jan 2021	Travel corridors suspended. (i.e. foreign travel suspended for non-essential purposes)