AN EXPLORATORY SPATIAL ANALYSIS OF ACCESS TO PHYSICAL AND DIGITAL RETAIL BANKING CHANNELS *

TECHNICAL REPORT

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Abstract

In this study, we measured the distance from the centroids of 42148 small statistical areas of the UK to the first and the second closest point of access to physical banking channels (ATM, Post Office, branch). Secondly, access to digital banking was approximated from geographic customer segmentation based on the distances to the nearest mobile base station and local telephone exchanges. Exploratory spatial data analysis at both UK and regional level showed strong spatial patterns; significant rural/urban clusters could be identified as well as a North/South divide which we need to explore further. No significant association was found between distance metrics and income and employment. Despite data limitations, the indicators used in this study can be used to identify "the void" areas, as well as areas vulnerable to the closure of the last points of access. We learned that the majority of the infrastructure for access is no longer operated by banks. In this context, it becomes even more critical to maintain and monitor a dynamic map of access and therefore we recommend more transparency on location, capability and capacity of the points of access from all players, as well as on broadband availability and quality from telecom providers. Retail banking access should be treated as a joined-up system so that territorial coverage can be ensured, such that entire communities are not accidentally excluded from participation in the economy.

***Keywords*:** Retail Banking, Infrastructure, Access, Exploratory Spatial Data Analysis (ESDA), Financial Exclusion, UK.

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1. Introduction

A retail banking "channel" allows a customer to interact with a bank and to initiate or execute financial transactions. The channels have evolved in time from branches, through ATMs and call centres, to online banking and mobile banking. Post Offices as well as the Third-Party Providers (TPPs) introduced by the Payment Service Directive 2 (PSD2) regulation, are banking channels as well. Despite banks' efforts to create a consistent, integrated experience across channels it is difficult to assess how customers experience the availability and accessibility of these channels. Akin to assessing access to public transportation, green spaces or supermarkets, "access" to financial services channels gives us additional information about the quality of life of the communities living in a certain space. Depending on their place of residence and their socio-economic characteristics, an individual could experience access to these channels very differently.

We believe that a measure for "access" to financial services through *both physical and digital channels*, has not yet been developed. This study is an early exploration in this direction.

Therefore, we take here ***a spatial, customer centric approach in order to assess the degree to which in the UK, local financial infrastructure allows people access to their own bank account in a cash or digital form.*** In our approach we draw on the vast statistical geography (Anselin & Rey, n.d; Arribas-Bel, 2019) and urban science literature (Ingram, 1971; Tan & Haining, 2009; O'Rourke & Briggs, n.d) looking at measuring access to points of interest like supermarkets (Jiao, Moudon, Ulmer, Hurvitz, & Drewnowski, 2012), healthcare or green spaces (Houlden, Porto de Albuquerque, Weich, & Jarvis, 2019).

Within the timeframe of this research[2], using open data, we attempt to explore methods for identifying areas in UK with reduced access to both physical and digital banking channels. Labelled *"The Void"* by the UK Financial Conduct Authority[3], this would be a situation where "customers can get 'stuck' or 'blocked' from accessing financial products and services because of physical ability or capability issues."

Our main research question is how to define and identify "the Void" areas in the UK?

In order to identify and characterise "the Void" we considered the following research sub-questions :

1. What measures of access to physical infrastructure points (ATMs, branches, post offices) give us a view of the current state?
2. What measures of access to physical infrastructure points can guide both the financial institutions and the regulators in maintaining adequate territorial coverage?
3. To which degree, based on open data, can we estimate the availability and the quality of fixed and mobile data broadband as pre-requisite digital infrastructure for using online and mobile banking?
4. Can we identify significant spatial patterns and associations with socio-economic factors such as income, employment, population density and age groups?

[2] January – July 2019

[3] Occasional Paper No. 17: Access to Financial Services in the UK (2016)

The Data section describes the data collection process and the choices made for sourcing data for addressing the questions above.

The Methodology section first describes the indicators of access, addressing sub-questions 1 and 2. We define *Distance 1* as the minimum distance between the centroid of a small statistical area and the closest ATM, branch or post office. We define *Distance 2* as the minimum distance between the centroid of a small statistical area and the *second* closest ATM, branch or post office. We then calculate the *Impact Index* as the difference between Distance 2 and Distance 1. We do this for all ATMs, branches and post offices as a whole set of access points and separately for branches only[4].

The Impact Index shows that some points of access are critical for some areas. More specifically, when Distance 2 is very large compared to Distance 1, it shows a high vulnerability of that area to the closure of the point of access (ATM, branch, post office) identified at Distance 1.

In order to explore possible definitions of "The Void", we combine the digital infrastructure availability (sub-question 3) with the measurements of physical infrastructure access (sub-questions 1 and 2). These measurements are calculated at UK and regional level. Where relevant, the measures of access are represented as maps.

We then address the sub-question 4 by calculating exploratory spatial data analysis indicators for identification and characterisation of spatial patterns at both national and regional level.

The Results section looks at the findings. The measurement of Distance 1 and Distance 2 showed Scotland as an outlier compared to the other countries[5], especially for the areas in the lower quantile for this measure. Focusing on the areas over the 5000m threshold for Distance 1 and Distance 2 we notice that most of the closest and second closest points of access are post offices. This highlights the importance of the post office as a banking channel for the "last mile". However, the income and employment indicators for these areas show that they are not the most deprived areas economically in the context of their countries[6]. Equally, the 227 branch closures identified in the period January-July 2019 are not in the most economically deprived areas either.

Spatial analysis at UK level shows strong autocorrelation for both Distance 1 and Distance 2 measurements. In other words, the distribution of the ATMs, branches and post offices is heavily clustered. Apart from a distinct urban/rural pattern which was to be expected, we observed a North/South divide akin to that observed by Arcaute et al. (2016). However, analysis of this observation is beyond the scope of this research and would require further analysis.

At the regional level we focused on one out of forty European administrative regions of UK: Gloucestershire, Wiltshire and Bristol and Bath area. We chose the area because it experienced the highest number of branches closures between January - July 2019 and this allowed for comparisons. We therefore focused only on branches and we found for both Distance 1 and 2 an even stronger spatial autocorrelation for these access points. More importantly, we showed that both the local indicators for spatial analysis for Distance 2 and the Impact Index can be used to proactively identify areas which are vulnerable to closures of specific points of access.

We then explored a combination of thresholds of access, for both physical and digital channels, and we learned that in areas like the one studied "the

[4] We could monitor the closures between Jan-July 2019 only for branches but not for ATMs or post offices.

[5] For Distance 1 see Figure 7, Table 2 and Figure 13. For Distance 2 see Figure 8, Table 3 and 14.

[6] See Appendix 7 and 8.

Void" as an extreme situation of lack of access is a small-scale, isolated and clearly identifiable phenomenon. What exacerbates the situations of reduced access are the socio-economic characteristics of the population affected. Those already economically vulnerable and with reduced mobility would be affected the most.

The Discussion section addresses the limitations of the current research and highlights areas of further research.

In the *Conclusions section*, we show that despite data limitations, we managed to build a *UK dynamic map for physical points of access to retail banking*. Our intention is to maintain this map and make it openly available.

We observed that the majority of the endpoints of access to banking are not owned or operated by banks. Given the separate dynamic of the different types of access points and the banking status as "national infrastructure", modelling this infrastructure becomes crucially important for managing its resilience and robustness.

We finish our report with *Recommendations* for the industry based on the current findings.

We recommend the industry does a quantitative assessment of access and of "banking capacity" of an area before closing access points, and this paper provides indicators for such assessments.

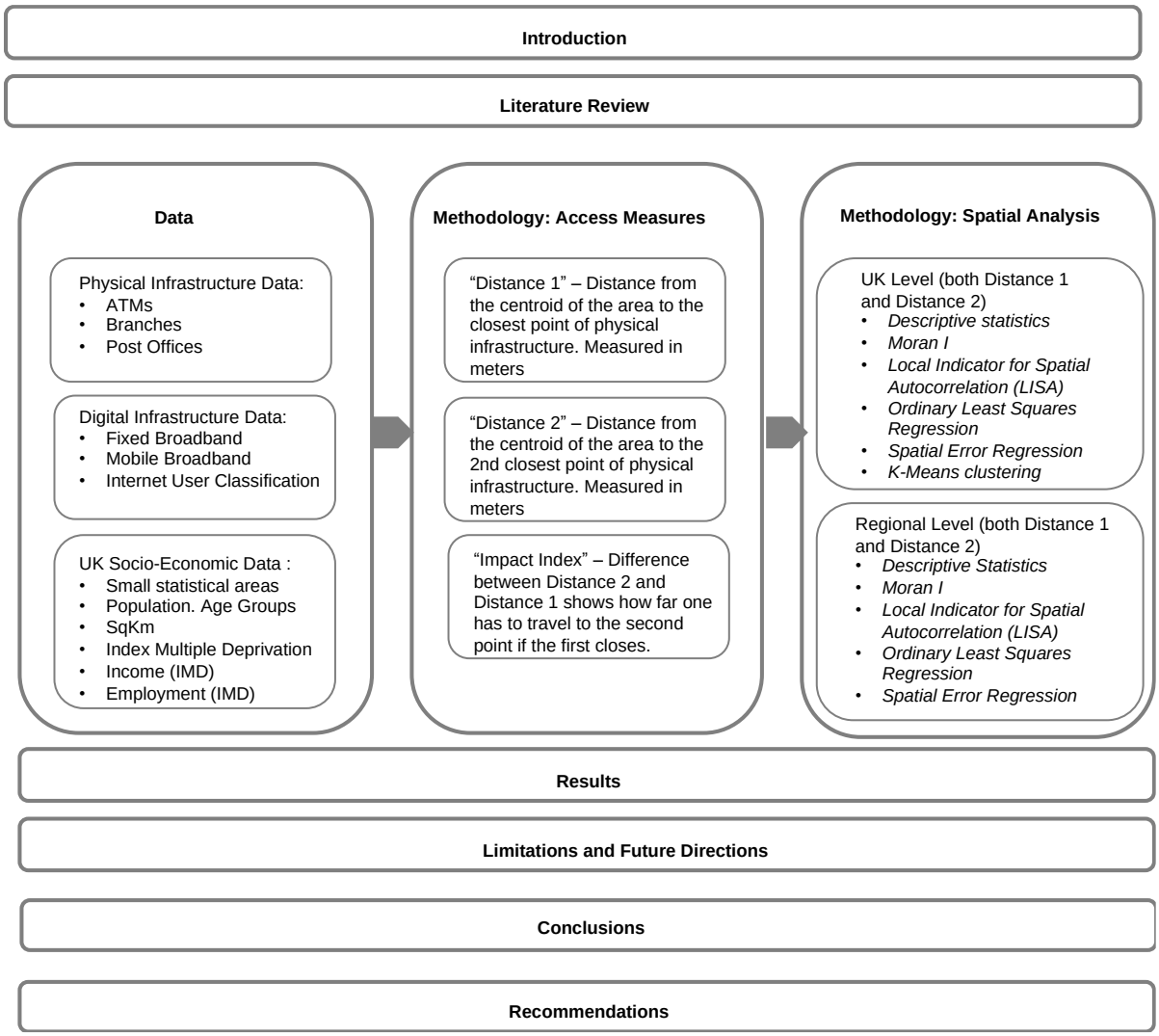
We support the Ceeney Review recommendations for the access points to retail banking to be treated as a "joined-up" system.

We recommend more transparency for retail banking players and telecom industry regarding the data points required for measuring access. The regulators should review the purpose of having APIs for branches, and ATMs for a small set of banks if the infrastructure landscape is inaccurately modelled.

Last but not least, the degree to which the mobile branches and outreach post offices satisfy the retail banking needs of the communities impacted, deserves further study.

For the full report structure see Figure 2.

Figure 1: Report Structure



2. Literature review

The question of "access" to financial services was generally addressed within the framework of economics and regional development, mostly as a matter of "financial exclusion" or "financial inclusion". In their seminal study "Access to Finance", Peachey & Roe (2004) emphasise that there are important conceptual differences between these terms due to the context within which they have been studied; in developed economies, access to financial services has been studied as a problem of "financial exclusion" and by extension of ***"social exclusion"***. In low-income countries however, "access to financial services" is coupled with access to basic services like clean water, electricity or minimal education and is looked at as a path for ***alleviation of widespread poverty***. In both situations, researchers address the extent of "access" to financial services. However, the economic context and, as a consequence, the size of the problem is very different: *"[T]he percentage rate of access* in poorer developing economies is about equal to *the percentage rate of exclusion* in richer advanced industrial economies" (Peachey & Roe, 2004, p. 9).

This study focuses on the UK so, we are necessarily building on the literature on financial exclusion in developed countries. We hold, however, a restrictive definition of the term, simply looking for the presence or absence of specific services[7] seen as essential for individuals to participate in a modern economy such as the UK.

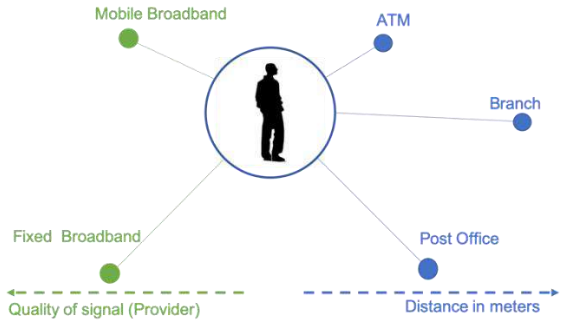
The presence or absence of a service has been proverbially difficult to measure. We therefore focus on the ***"points of access" to financial infrastructure*** which give individuals access to a very basic service: access to their own bank account in cash or digital form. We do not include other forms of financial exclusion like self-exclusion or exclusion from accessing more complex products based on price or banks' risk assessment.[8]

[7] We take the view that basic financial services fulfil the criteria of universal services as defined by the European Commission. The universal services "should be provided in a continuous way, meet specific requirements in terms of quality and affordability, in order to be accessible for everybody, and comply with user and consumer protection standards. The general examples provided include network services (energy, transport, telecommunications) and, as far as non-economic services are concerned, justice, safety, national education and a compulsory basic social security scheme." (Anderloni & Carluccio, 2007, p. 24). Only Germany, Austria and Sweden consider the supplying of comprehensive financial infrastructure to provide teritorial coverage to be withing the remit of a "service of general economic interest" as defined by the EU Commision.

[8] (Kempson, Whyley, Caskey, & Collard, 2000) as cited by Anderloni & Carluccio (2007) lists the following exclusion categories of causes/forms of financial exclusion:

- "geographical access", referring to the existence of bank and counter services in particular geographical areas;
- "access exclusion", referring to restricted access as a result of banks risk assessment processes;
- "condition exclusion", the conditions relating to financial products offered mean that they fail to meet the needs of some groups of clients;
- "price exclusion", charges associated with products or services that are too high for some individuals;
- "marketing exclusion", some market segments are specifically excluded by the way marketing and sales are targeted;

Figure 2: A person experiences the access to financial services channels differently depending on his place of residence.



These "points of access" are customarily called "banking channels" in the industry. The channels have evolved in time from branches through ATMs, call centres to online banking and mobile banking. Additionally, in the UK, the Post Office offers a "limited set of banking services" to the clients of a number of UK banks. This makes post offices a banking channel as well (Vennells, 2018). Furthermore, the Payment Service Directive 2 (PSD2) regulation, has introduced new types of players, which typically have only a digital presence and who can initiate payments or create new business models based on banking data. They too form a new banking channel. For years, banks have invested in "making the movement between channels seamless" (Rizzi & Taraporevala, 2019) whilst the usage of the channel mix is continuously metamorphosing. *"We've gone from being dependent on the branch to provide the utility of "the bank", to just being dependent on the utility of "a bank"."*(King, 2013, p. 89).

Kempson, Whyley, Caskey, & Collard (2000) and Beck & de la Torre (2006) defined the "geographic exclusion" component of the financial exclusion as "*the absence of bank branches or delivery points"* and call these points "financial infrastructure". Peachey & Roe (2004) emphasised the "geographic exclusion" as "probably the most significant *new* dimension of the problem". Beck, Demirguc-Kunt, & Martinez Peria (2007) have done a comparative study across countries which measures the geographic and demographic branch and ATM penetration as number of points per 1000 km^2 or per 100,000 people. Since these studies were published, the adoption of digital channels has grown and the local access to banking has also become a question of availability as well as the quality of fixed and mobile data broadband.

Existing studies typically explored a static view of separate physical banking channels, ignoring access to digital channels. As the banking channels mix is in continuous change, we observe a gradual closure of the physical points of access and an increased adoption of the digital ones. Consequently, we should extend the definition of "geographical exclusion" and "financial infrastructure" to include all channels.

Ceeney Review (Ceeney, 2019, p.65) states that "cash use has halved in the last ten years and is forecast to halve again in the next ten. […] As volumes drop, the unit cost for processing cash is likely to rise". The economics of the current cash infrastructure designed for a higher volume cash society do not hold for the low, infrequent cash use. Given that the infrastructure is run by commercial entities, as they become unprofitable, they will inevitably close. This is visible through the **closures of ATMs** which are just one component of the large cash infrastructure estimated to cost UK £5bn per year to run (Ceeney, 2019).

The Post Office Network infrastructure is changing as well. However, the lack of transparency means that it is difficult to map how it is changing, thus obscuring the potential impact. The National Federation of Subpostmasters (NFSP) states that

- "self-exclusion", referring the fact that some parts of the population refuse to approach banks, believing that any request for products or services would be turned down.

according to their internal surveys, 22% of subpostmasters plan to close, downsize or hand-on their post office in the next 12 months, equating to 2500 offices (National Federation of Subpostmasters, 2019, p. 5.)

There are many reasons why the UK Post Office Network is under this strain. The Parliamentary Inquiry recorded many complaints especially about the unfairness and lack of profitability of the "banking framework" under which the Post Office deliver "basic banking services" (Post Office Network Parliamentary Inquiry, 2019) Kelly Tolhurst MP (2019) said the "Post Office Ltd is delivering a service for the banks, but it should not be an easy option for the banks to pull away and expect the Post Office to pick up the slack".

As mobile and online banking become the channel of choice for many customers, the footfall in branches decreases, **branches** become unprofitable and they get closed. In his highly popular book focused on the shifting banking landscape, King (2013, p. 96) warned the banks: *"you need to work out* ***a transitional approach****—an approach that bridges the new behavior of customers, and that caters for the psychology of legacy customers who have long memories or entrenched behavior".*

We are definitely in the transition period, but the "transitional approach" is by no means clear. The "Access to Banking Protocol" agreed by the Government and banking industry in 2015 "recognizes the banks' absolute right to close branches" and it only requests banks to "engage with communities" about post-closure provisions and "put in place alternatives if a continued need for banking services is identified" (Access to Banking Standard – LSB, 2017). There is no obligation for an impact assessment of the closure but only for an information provision.

A transitional approach would require a way of measuring a base state of territorial coverage as well as a way of monitoring the gradual move towards a different state. The industry should at least try to avoid the occurrence or extension of "Void areas".

3. Data

3.1. Physical Infrastructure

Thirteen banks in the UK provide data about their branches and ATMs through Open Banking APIs[9]. However, the number of financial institutions is much larger, so for the rest of the institutions we have web-scraped their websites. The **banking branches** dataset used for most of the analysis in this study is based on data extracted in February 2019[10]. The **ATMs** dataset was web-scrapped from the Link Scheme public website[11]. Given that over 70% of the ATM locations[12] are run by non-banks acquirers, we used the Link Scheme locations for this study, not the locations provided by the banks through Open Banking APIs. Through this method, we captured locations which might host one or more ATMs which are not distinguishable individually. Hence, in this study, the total number of individual ATMs in the UK remains unknown.

The **Post Office** dataset is based on data provided openly by the Post Office[13]. The Post Office does not have APIs for its branches akin to that mandated on some large UK banks by the Competition and Markets Authority. We therefore cannot know, similarly to banks' branches, which post offices have closed between January-July 2019. We don't know if an individual post office is Crown, agency or outreach branches nor what their opening hours are. This poses some problems that will be explored later.

3.2. Digital Infrastructure

In order to access online and mobile banking, people depend on the availability and the quality of fixed and mobile broadband data in the areas they reside or where they try to access these channels.

The telecom industry regulator, OFCOM, provides information about fixed and mobile broadband thorough file downloads[14] and APIs[15]. The files provide information at Local Authority level which is a too high-level for the purpose of our research. The APIs provide such a generic characterisation of the broadband quality that it makes the result unusable.

Thus, we have used for the **fixed broadband data** a dataset provided by Consumer Data Research Centre (CDRC) which offers information at postcode and Output Census Area code based on May-June 2017 extracts (O'Brien, 2017). The UK government Universal Standard Obligation (USO) pledges that everybody in the UK will have the legal right to request a 10 Mbps+ capable "high speed broadband" connection from 2020[16]. However, for the purpose of being able to access online banking, a lower quality broadband would be enough. As a proxy for being able to use online banking channels, we calculated the percentage of households that has access to fixed broadband of over 2 Mb. We did so for each small statistical area.

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[9] Open Data API Dashboard — Developer Zone — Confluence, (n.d.)

[10] See "Appendix 1: Number of physical and mobile banking branches by brand, UK, February 2019"

[11] LINK / ATM Locator, (n.d.)

[12] See Appendix 2: Number of ATMs Locations by ATM Acquirer, UK (March 2019)

[13] Locations Post Office (2018)

[14] OFCOM, Data downloads, (2017)

[15] OFCOM, Dev Portal, (n.d.)

[16] According to the UK government Universal Standard Obligation, a "good" fixed broadband requires a download speed of at least 10 Mbps and an upload speed of at least 1 Mbps.

Neither OFCOM nor CDRC provide similarly low granularity data for mobile broadband which limited our attempt to calculate access to digital banking channels.

We have, however, used a category of the Internet User Classification for England called "**Constrained by infrastructure**" (Singleton, Nguyen, Alexiou, & Riddlesden, 2014). According to Singleton et al. (2014), in these areas, the *"fixed line broadband performance falls significantly below the national average"* and *"distances to local telephone exchanges are much higher. Distances to the nearest mobile base station for cellular and data coverage are also higher than the national average".* However, this is not a perfect measure for digital infrastructure as this dataset was produced in 2014 and the situation might have changed.

3.3. UK statistical areas and socio-economic factors

The UK map was built using Lower Layer Super Output Areas (LSOA) for England and Wales, Super Output Areas (SOA) for Northern Ireland and Datazones (DZ) for Scotland. We call these areas collectively small statistical areas. For all of them we sourced their area, total population and population by age groups, their correspondence with Census Output Areas, Local Authorities and NUTS2[17] areas. Finding socio-economic factors applicable to the whole UK is not easy because of the devolved nature of the statistical functions in England, Scotland, Wales and Northern Ireland. When comparing UK countries, we used the income and employment components of the UK level Index of Multiple Deprivation (Abel, Barclay, & Payne, 2016).

3.4. Data processing

All the data sources above contributed to the creation of a "master file" which was afterwards used for analysis. The merger of the data sources is presented in Appendix 1: Data Sources.

[17] NUTS2 are Nomenclature of Territorial Units for Statistics used at European Level. UK has 40 NUTS2 areas.

4. Methodology

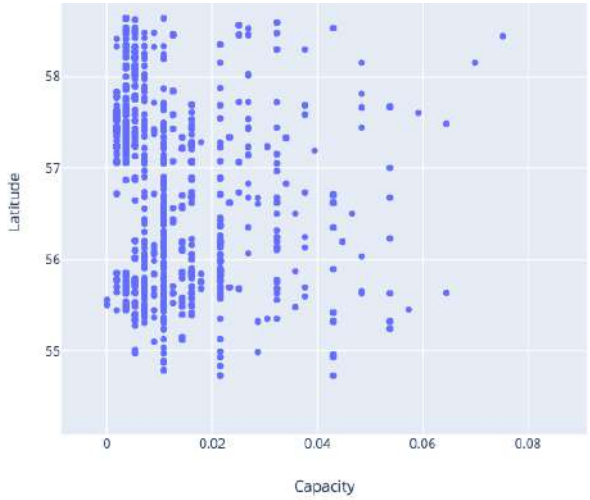
4.1. Capacity and Capability of a point of access

We define the **"*capability*"** of a point of access, as the set of services of financial nature that can be satisfied at that point of access. At an ATM one can withdraw cash and check the account balance. In a post office, one could also make cash deposits and certain payments. A typical branch would allow most services whilst a mobile branch can facilitate merely a subset of those[18]. As we cannot get the capability information for the points included in our dataset, we take the lowest common denominator – access to one's own bank account in cash or digital form. We define the **"*capacity*"** of a physical point of access as:

$$\text{Capacity} = t/46.5\text{h}$$

where t is the number of hours per week that point is open. 46.5h is the number of hours a typical physical branch is open per week. A branch open 46.5h/week will have a capacity of 1, while a mobile branch[19] open just 10 minutes per week will have a capacity of 0.0036. Branches open for longer than 46.5h/week will have a capacity over 1[20]. Figure 3 shows the capacity of all the mobile branches of the Royal Bank of Scotland (RBS) against geographical latitude. 751 out of the total of 939 mobile branches of RBS have a capacity of under 0.02 of a physical branch of RBS[21]. The total capacity of all RBS mobile branches is less than the capacity of 12 full time branches.

Figure 3: Royal Bank of Scotland. Mobile branches capacity against geographical latitude (February 2019).



[18] For mobile branches services see: Bank of Scotland | Mobile branch (n.d.); Mobile Branches | Royal Bank of Scotland (n.d.); Lloyds Bank | Banking with us | Mobile Branches (n.d.); Natwest | Mobile Branches' (n.d.).

[19] The term "mobile branch" is used in the industry interchangeably to represent a bank owned van serving as a branch or the stop of the respective van. In this report we will call "mobile branches" the van stops, as this is what the banks report through the Open Banking APIs.

[20] See physical branches of LBG in Figure 5.

[21] Electronic supplementary material available on *github.com/andrasonea/TFI_AccessToBanking* "RBS mobile and physical branches capacity. July 2019".

Figures 5 and 6 show the capacity and spatial distribution of mobile and physical branches of both LBG and RBS. We see a marked difference in capacity not only between mobile and physical branches but also between the physical branches of the two banks.

We know that there is a similar variance in the capacity and capability of the post offices too. There are three types of post offices: Crown, agency or outreach office[22]. The outreach services are "typically small part-time branches that may use a village hall or mobile van to provide post office services to communities". They are in this sense very similar to the mobile banking branches. While we could identify the mobile branches of the large banks, we could not link the type of post office to a specific location.

Based on the capability and capacity considerations above, we decided to eliminate the mobile branches from the calculation of access indicator so as not to present misleading information about the extent of services present. We could not similarly eliminate the outreach post offices.

4.2. Distance 1: access as "distance to the closest point of physical retail banking infrastructure"

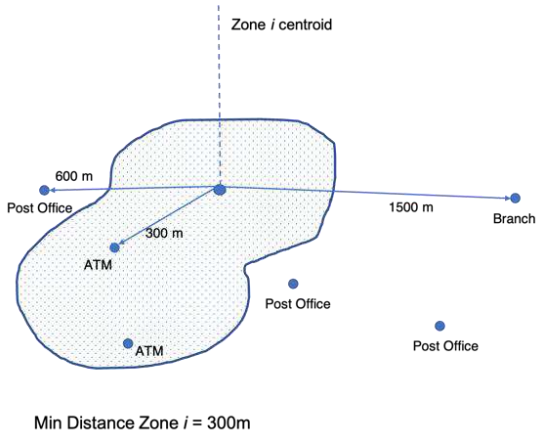
Once we established the set of points[23] which allow almost equal access to the basic service considered, we measured the straight-line (Euclidian) distance from the centroid of each statistical area to the closest ATM, closest branch and closest Post Office (see Figure 4). We decided to use Euclidian distance instead of street network, because one of the very few spatial "access criteria" in financial services are the ones for Post Office, and they are expressed as straight-line distance from the centre of postcode areas (Brown & Booth, 2018)[24].

Using QGIS distance matrix function, we calculated for all 42148 statistical areas the distances in meters to the closest point of physical infrastructure. We then considered:

Distance 1 = min (*Distance to the closest ATM, Distance to the closest branch, Distance to the closest post office*)

where distance is calculated in meters and measured from the centroid of each small statistical area. Distance 1 is an indicator of the *current situation* for spatial access to physical retail banking infrastructure.

Figure 4: Calculation of the minimum distance from the centroid of a statistical area to a point of physical retail banking channel (Distance 1).



[22] At the end of March 2018 there were 9768 agency branches, 1517 outreach services and 262 Crown branches (Brown & Booth, 2018, p. 7).

[23] The dataset includes 50190 ATM locations, 7340 physical branches and 11547 Post Office (Feb-March 2019).

[24] See Appendix 4: Access Criteria to the Post Office

Figure 5: Lloyds Bank. Spatial distribution and capacity of mobile and physical branches (July 2019).

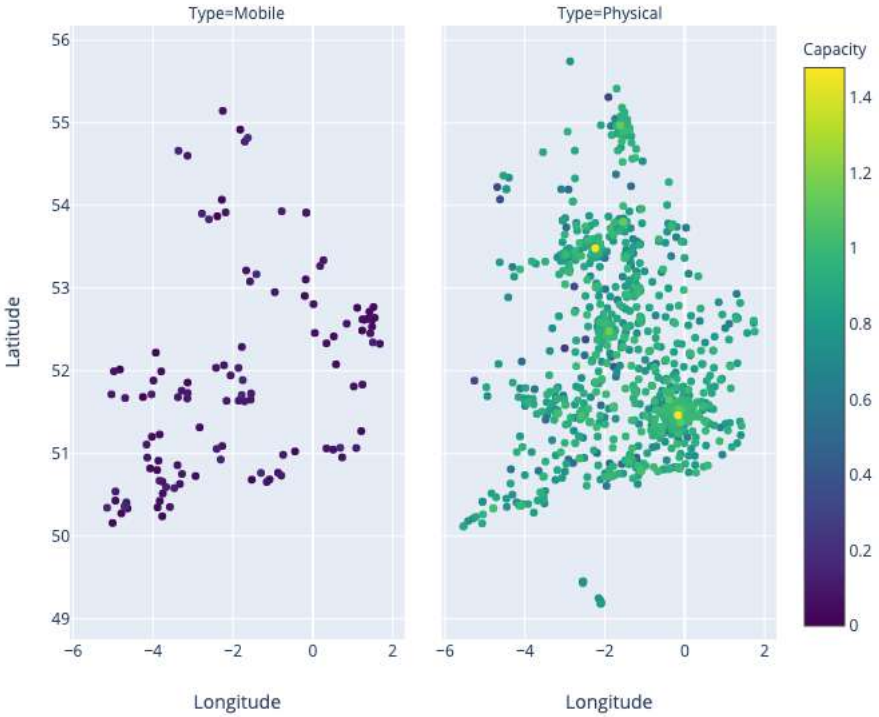
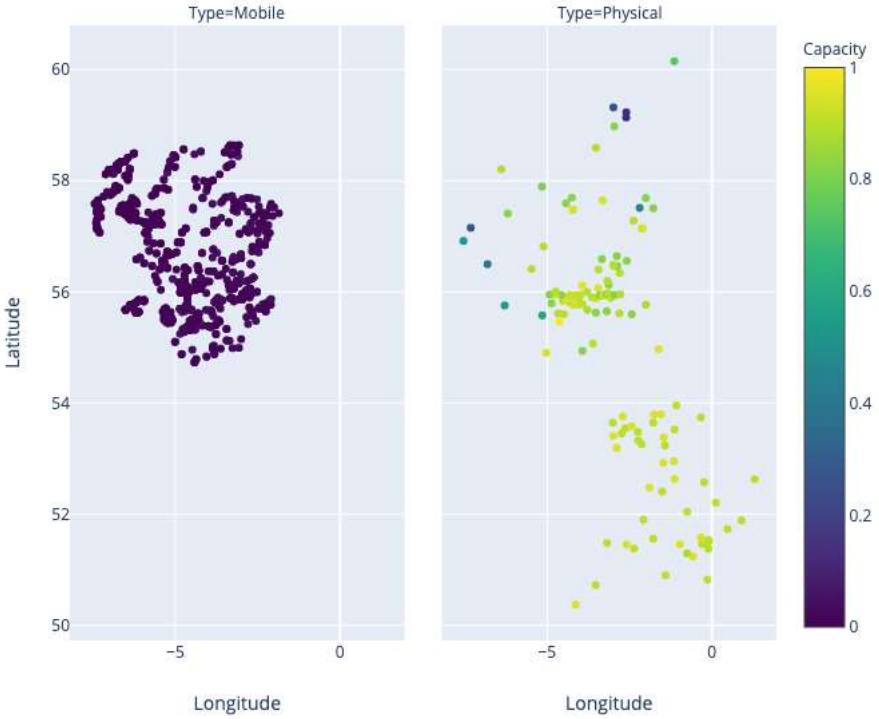


Figure 6: Royal Bank of Scotland. Spatial distribution and capacity of mobile and physical branches (July 2019).



Note for Figure 5 and Figure 6: Capacity of 1 is 46.5h/week.

4.3. Distance 2: access as distance to the second closest point of physical retail banking infrastructure

Banks, building societies and the Post Office network are each under pressure to close certain points of access and have different incentives for opening others elsewhere. In order to understand the geographic variation induced by closures of points identified as "closest" we calculate:

Distance 2 = min*(Distance to the 2nd closest ATM, Distance to the 2nd closest branch, Distance to the 2nd closest post office*)

where distances are calculated in meters in a straight-line from the centroid of each small statistical area and taking into consideration the whole dataset of access points.

4.4. Impact Index

We then define an Impact Index as follows:

Impact Index = Distance 2 – Distance 1

Table 1: Thresholds for measuring impact of closure of a point of physical retail banking infrastructure.

Impact Index	Threshold: difference between the distances to the closest point and second closest point of physical retail banking infrastructure
Impact 1	< 1000 m
Impact 2	1000m – 5000m
Impact 3	5000m – 10000m
Impact 4	>10000m

For example, we allocate an Impact Index of 4 to those points of infrastructure – ATMS, Branches or Post Offices which fall within an area with an Impact Index of 4. In other words, if a point of access with an Impact Index of 4 closes, we know that the next point of access of the same type for that area would be at over 10,000m more than the first point [25]. When a small statistical area is labelled with Impact Index 4 we know that the area is very vulnerable to the closure of the current closest points. We acknowledge that the impact of closures also depends on the geographic and socio-economic characteristics of the areas affected. However, one can safely infer that points categorised as Impact 3 or 4 would have the largest negative externalities, especially in economically deprived areas. See also the digital map on the TFI website.

4.5. Access to digital channels

The adoption of digital channels is typically assumed to result from personal preferences and sufficient skills. However, in this study we consider the availability of broadband which would be good enough to allow a person to consistently and confidently do financial transactions online. We considered two measures as indicators for the digital infrastructure required to have access to digital banking:

- % of premises that cannot get 2Mbs fixed broadband (O'Brien, 2017)
- "constrained by infrastructure" category from the Internet User Classification (Singleton et al., 2014)

4.6. Spatial Analysis at UK and regional level

We used classical exploratory spatial data analysis (ESDA) methods at UK and regional level: global and local spatial autocorrelation, spatial regressions, k-means clustering, and various visualization techniques.

Moran's *I* is a global indicator of spatial correlation. The null hypothesis is that of spatial randomness for the phenomena observed. Applied to our indicators of access - Distance 1, Distance 2 and Fixed Broadband - the spatial randomness would mean that the values for these indicators in one location do not depend on the values for the same indicators in

[25] See additional electronic materials on *github.com/andrasonea/TFI_AccessToBanking*

the neighbouring locations. For the whole space studied, Moran's *I* is a unique value indicating whether the phenomenon studied is spatially clustered or not.

We then calculated univariate and bivariate *local indicators for spatial association (LISA).* This allows for the decomposition of the global Moran indicator of spatial autocorrelation in clusters and outliers.

We run Ordinary Least Squares regression (OLS) and Spatial Errors regressions (SE) as we tried to observe the possible relationships between dimensions of access to retail banking channels (Distance 1, Distance 2, Impact Index, % of premises which cannot get 2Mbs fixed broadband, "constrained by infrastructure" category) and the socio-economic characteristics of UK regions and small statistical areas (income, employment, deprivation, proportion of population over 65 years old).

4.7. The Void

"The Void" is a situation where "customers can get 'stuck' or 'blocked' from accessing financial products and services because of physical ability or capability issues." For this study, we assumed that customers would be severely "blocked" from accessing both physical and digital channels due to a matter of the required physical and digital infrastructure being absent or being present to an insufficient level in their area of residence.

What "The Void" means though, is still a matter of wider regional context. A rural area characterised by high deprivation would lead to its residents feeling certain levels of access as very restrictive, while the same level of access would be acceptable for a wealthier, more mobile population. Because of this, we believe that static thresholds do not make sense as categorisers of "the Void". However, the combination of the indicators of access described would allow us to identify the most "underserved" areas within a wider region, areas which in extreme cases can be characterised as "the Void".

For the distance measurements we considered the following thresholds: 1000m, 3000m, 5000m, 10000m as well as the distances in meters used in the Post Office Access Criteria (1609m, 4828m, 9656m). In addition, the areas labelled as "constrained by infrastructure" would indicate a serious limitation of access to both online and mobile banking channels. This could be refined by identified areas where more than 20% of the premises cannot get at least 2Mbs.

5. Results

5.1. Distance 1

Mapping Distance 1 at UK level only allows us to see **large differences between dense urban concentrations and the rest of the territory** (see Figure 13). In the histogram in Figure 7, Scotland stands out with a tail of areas for which the closest point of physical financial infrastructure is at more than 10000m. This distance is way above the thresholds for access to Post Offices, despite including the ATMs and the branches in this measurement as well. Such big distances could most likely be explained by the mountainous geography, and the large number of islands in Scotland compared to England, Wales and Northern Ireland. We also need to emphasise that using Euclidian distances gives us the minimum distance between two points which, in the context of Scotland in particular, could be very misleading. The street network distances would be considerably longer.

Based on data from February-March 2019, 32,728 of these "closest points" for UK areas are ATMs, 8,368 are Post Offices and 1,053 are bank branches.

If we only focus on the small statistical areas where **Distance 1 is bigger than 5000m**, we see that in terms of income or employment they are not necessarily the most deprived areas[26] as popular press would lead us to believe. However, we notice **important disparities between the countries**. Northern Ireland's lower quantile shows significantly lower income and employment and higher deprivation than the other countries[27]. This highlights that the same degree of access measured as a distance can be experienced very differently by someone in Northern Ireland than in England.

It is also interesting to point out the mix of the points of access for the areas where Distance 1 is larger than 5000m: 153 post offices, 78 ATM locations, and 11 branches. This highlights a strong reliance on post office locations.

5.2. Distance 2

The Distance 2 UK map shows that Scotland, Northern Ireland and Central Wales would be the regions with the highest Impact Index. In other words, the second closest points of access are at a considerable distance to the first (see Figure 14).

Looking then only at small statistical areas where **Distance 2 is bigger than 5000m** we find that 1,379,825 people in UK live in such areas and 24% of those are over 65 years old. The post offices remain the dominant type of points of access for this measurement, too. 828 of these critical points are post offices, 172 are ATMs, and 38 are branches. We observe again differences between the socio-economic characteristics of the countries with Northern Ireland's areas being significantly more deprived than areas in the rest of the UK within the same access bracket. We would have liked to monitor the closures for all the types of points of access over the period of this study, however, this was possible only for branches. The Post Office does not publish their locations regularly, and monthly web-scraping of the ATM locations would have been too onerous. We found that 227 branches have been closed in this period. 55 branches opened, out of which 22 are mobile[28]. Despite the wide-spread view that the closures happen in the most economically deprived areas, this is not the case for the time window Jan-July 2019.

[26] See Appendix 5.

[27] See Appendix 7 and 8

[28] See Tables 4 and Appendix 6.

Figure 7: Histogram for Distance 1 for England, Scotland, Wales and Northern Ireland.

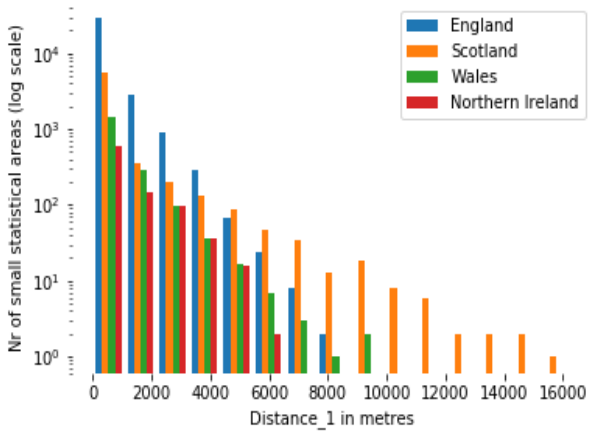


Figure 8: Histogram for Distance 2 for England, Scotland, Wales and Northern Ireland.

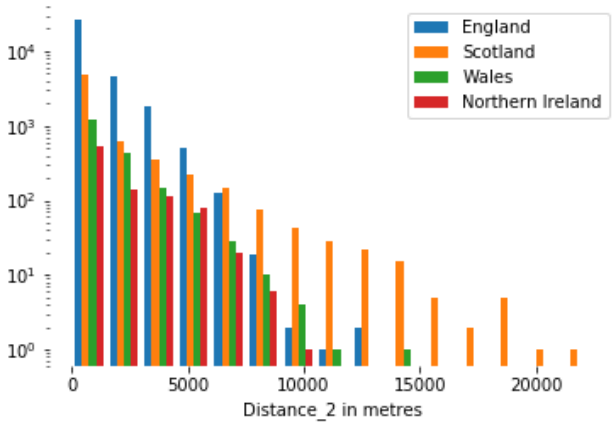


Table 2: Descriptive statistics for Distance 1 by country (March 2019). Distances are measured in meters.

Country	Nr of small statistical units	mean	std	min	25%	50%	75%	max
England	32844	579.00	662.97	3.99	214.54	367.55	654.48	8615.10
Northern Ireland	890	1052.29	1122.89	6.20	278.10	562.40	1459.46	6252.30
Scotland	6506	760.07	1378.96	2.61	191.41	325.26	584.55	16325.55
Wales	1909	845.30	989.08	1.80	258.54	498.43	1037.81	9024.42

Table 3: Descriptive statistics for Distance 2 by country (March 2019). Distances are measured in meters.

Country	Nr of small statistical units	mean	std	min	25%	50%	75%	max
England	32844	1161.74	1065.65	5.68	521.61	796.64	1329.82	12927.28
Northern Ireland	890	1965.64	1739.13	113.79	696.57	1190.77	2987.78	9250.01
Scotland	6506	1580.27	2172.38	34.22	521.60	776.13	1422.49	22545.43
Wales	1909	1632.53	1496.73	35.87	677.51	1141.35	1980.62	13894.53

It could be that closures started in economically deprived areas. However, closures are so widespread nowadays that we do not find a significant correlation between the economic characteristics and the recent closures.

5.3. Fixed and mobile data broadband

Figure 11 shows the percentage of premises in small statistical areas that cannot get a fixed broadband of at least 2Mbs[29]. This threshold is lower than the USO[30], but it is enough for online banking. Most of the country has a good coverage at this level, with the exception of areas in Scotland, Northern Ireland, Central Wales and Cornwall.

Figure 10 shows the mobile data 'geographic coverage'[31] for all operators, as reported by OFCOM. Despite not being able to identify blackspots based on this data, we notice that the areas that are underserved for other types of access infrastructure (Scotland, Northern England, Central Wales, Cornwall), also have the lowest levels of broadband coverage.

Because the OFCOM mobile data geographic coverage is not granular enough, we instead used the "Constrained by Infrastructure"[32] category of the Internet User Classification (2014) (see Figure 12, in blue).

Table 4: Branch closures (Jan – July 2019[33]).

Bank	Type	Jan '19	Feb '19	Apr '19	Jul '19	Total
Bank of	Physical			6	2	8
Scotland	Mobile			1		1
Barclays	Physical			2		2
Danske	Physical			2		2
Halifax	Physical	3		1	9	13
LBG	Physical	48	7	21	23	99
NBS	Physical		1			1
Santander	Physical	5		66	30	101
TOTAL		**56**	**8**	**99**	**64**	**227**

[29] See Figure 11

[30] Figure 9 shows the proportion of premises in a Local Authority area that cannot get a download speed of 10Mbs. This level is considered "good" according to the government's Universal Service Obligation.

[31] The geographic coverage represents the percentage of landmass where good coverage is likely to be available. OFCOM states that "this metric is useful to describe the coverage that a consumer will experience when using their phone outside or on the move between outdoor locations" (OFCOM, 2016).

[32] See Figure 12.

[33] Numbers exclude RBS, Natwest and all the other UK banks which do not have Open Banking APIs, and for which accurate monthly monitoring was not possible.

Figure 9: % of premises in a Local Authority below the Universal Service Obligation threshold for fixed broadband *(*OFCOM, January 2018).

Figure 10: % of landmass covered by mobile broadband by all operators (OFCOM, September 2018).

Figure 11: % of premises which cannot get 2Mbs fixed broadband *(*OFCOM & CDRC. LSOA/SOA/DZ, May - June 2017).

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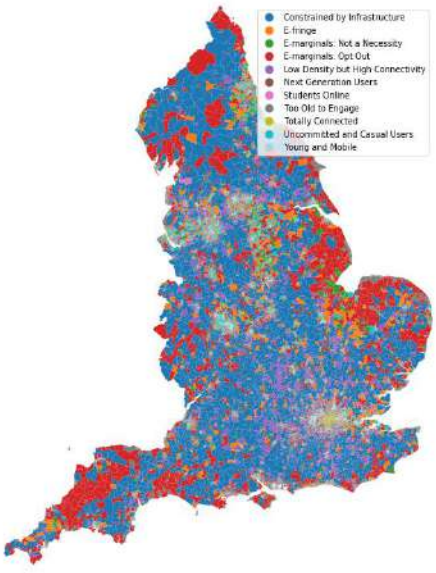
Figure 12: England Internet User Classification (2014).



5.4. Spatial Analysis at the UK level

Following the descriptive statistics calculations for the indicators of access to financial services channels, we then calculated global and local measures of spatial autocorrelation.

Spatial autocorrelation is defined as the degree of relatedness of a set of spatially located data.

The Moran's *I* test statistic was significant for both "Distance 1" (Moran's *I* = 0.5377, p=0.001) and "Distance 2" (Moran's *I* = 0.7566, p=0.001).

This means that the measurement of "access" as distance from the centroid of a small statistical area to both the first point of infrastructure and the second point of infrastructure shows **strong spatial autocorrelation.** In other words, the spatial distribution of physical end points for access to financial services (ATMs, branches, post offices) is clustered.

Moran's *I* statistic is only an indicator summarising an entire study area. In order to identify local clusters though, we calculated univariate and bivariate *local* indicators for spatial association (LISA). This allows for the decomposition of the global Moran indicator of spatial autocorrelation in four "spatial clusters". If an area shows a high value for the variable observed, and it is *surrounded by* neighbours also displaying a high value, this area will be grouped in a "High-High" cluster. Similarly, when an area displays a low value for the variable observed, and it is *surrounded by* areas also displaying low values, it will be grouped in "Low-Low" clusters. The outliers will be "Low-High" or "High-Low". A "Low-High" area is characterised by a small distance to a point of physical infrastructure, but it is surrounded by areas with a long distance to their closest point. The "High-Low" is the inverse of "Low-High"

The Low-Low clusters marked in blue in Figures 15 and 16 clearly show the urban areas that concentrate most of the financial services' physical infrastructure for access.

Figure 13: *Distance 1:* Distance in meters to the closest point of physical retail banking infrastructure (Feb 2019).

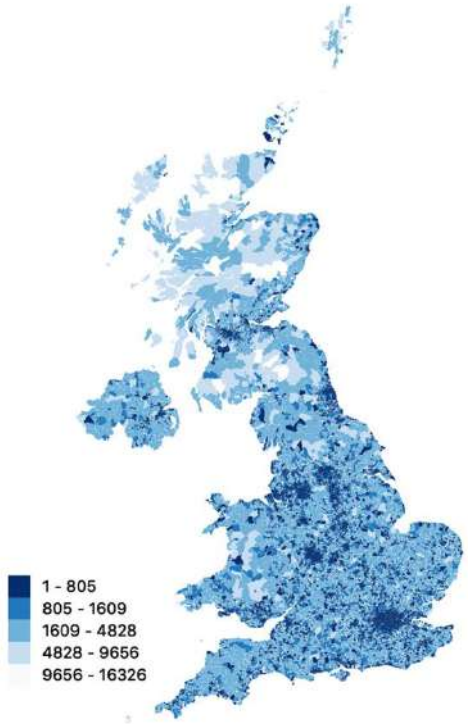


Figure 14: *Distance 2:* Distance in meters to the 2nd closest point of physical retail banking infrastructure (Feb 2019).

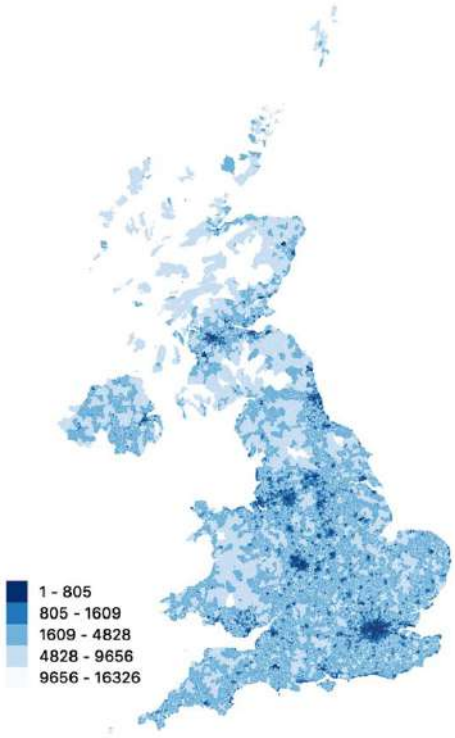


Figure 15: *Distance 1*: LISA clusters for distance to the closest infrastructure point (Feb 2019).

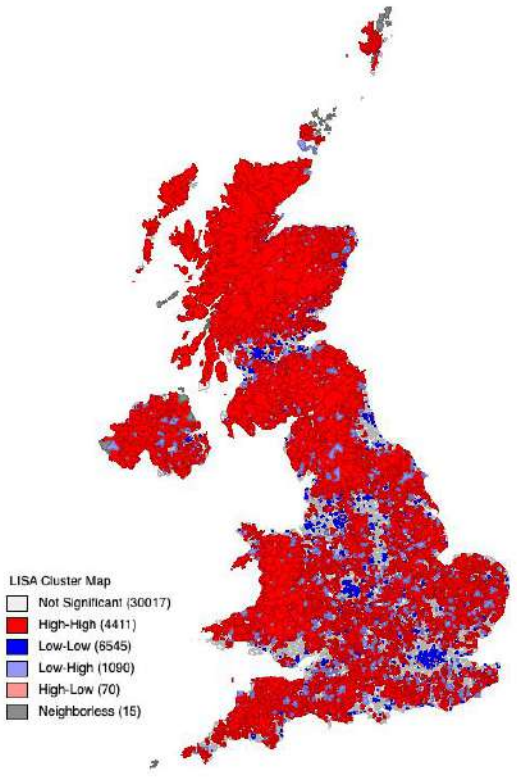
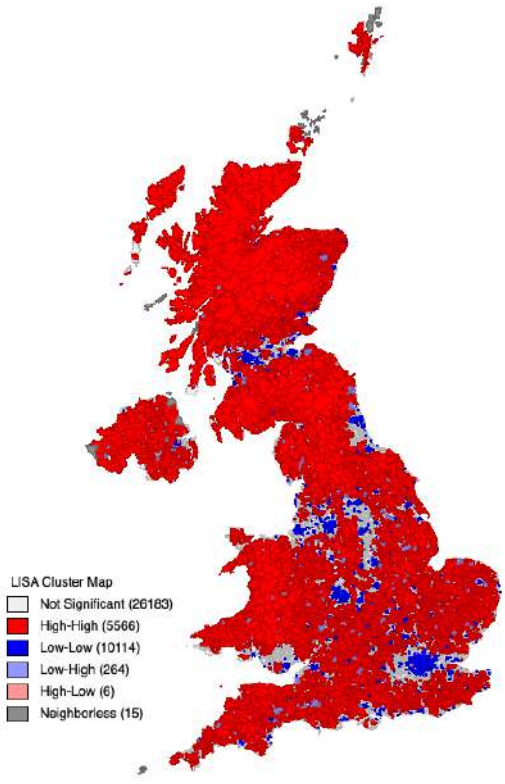


Figure 16: *Distance 2:* LISA Clusters for distance to the 2nd closest infrastructure point (Feb 2019).



We also identified spatial clusters based on a combination of the variables for physical and digital access: “Distance 1” and “Fixed broadband availability”. The latter variable was expressed as a percentage of premises which cannot get 2Mbs fixed broadband data. The K-means algorithm using Euclidian distances showed a clustering which is worth further investigation (see Figure 17). The cluster concentrated around London and the South-East of England seems to separate from the rest of the clusters by a line labeled as **the “North-South Divide”** (Arcaute et al., 2016). They looked to discover the regional “fractures” of Britain by applying percolation to Britain’s street network. She suggests that the North-South divide line, separating the urban structures studied, can be similarly drawn if one looks at the household income for the European administrative regional divisions (NUTS2). They also identified that the urban clusters formed through her method of research show that “Scotland can be clearly distinguished as a separate region from the rest of England and Wales”. Our maps also display very **different patterns for Scotland**.

This initial analysis at the UK level shows us that the UK countries, as expected, are quite different. Even though we may not find a *UK level* explanatory model for the spatial distribution of the access endpoints to retail banking, we should probably be able to find such models at the country level or regional level.

Figure 17: K-means clusters based on both distance to the closest infrastructure point and fixed broadband availability and quality.

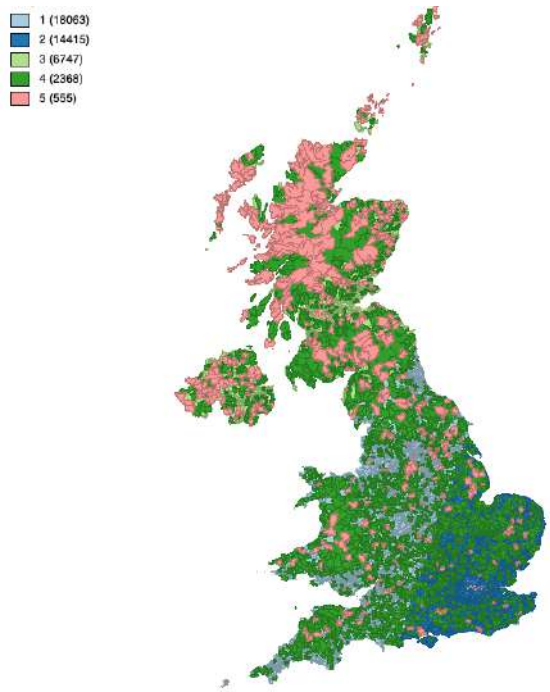
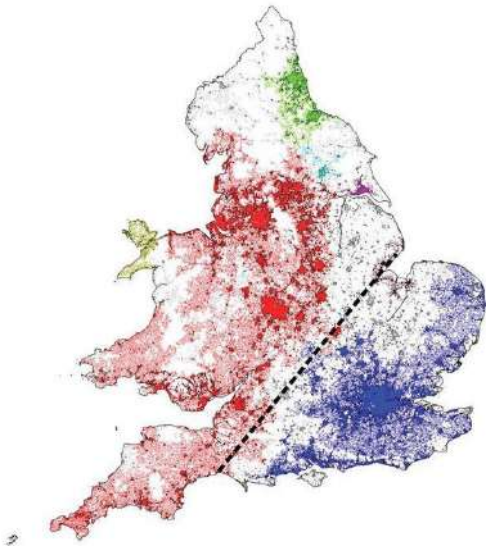


Figure 18: Map of England and Wales at percolation distance threshold d = 740 m. (Arcaute et al., 2016).



5.5. Spatial analysis at regional level

We ran detailed analyses on several out of the forty European administrative regions of UK (NUTS2). Here, we only present the example of the Gloucestershire, Wiltshire and Bristol/Bath area. NUTS2 code for this area is UKK1. At a regional level, we applied the same spatial analysis method as at the UK level, however, now only looking at branches (not all access points).

The slope of the linear regression through the Moran scatter plots for Distance 1 and Distance 2 (Figure 19 and Figure 20 respectively) corresponds to the Moran's *I* coefficient or test statistic for global autocorrelation. The horizontal axis represents the standard deviation units for Distance 1 and Distance 2. The vertical axis represents the standardised average of the neighbours for the same dimensions. Significant Moran's *I* test statistics resulting for both Distance 1 (Moran *I* = 0.799, *p* = 0.01) and Distance 2 Moran *I* = 0.799, *p* = 0.01) indicate that the null hypothesis of spatial randomness should be rejected.

Figure 19: UKK1 NUTS2 Area. Gloucestershire, Wiltshire and Bristol/Bath Area. Moran I and LISA clusters for distance to the closest branch (Distance 1, February 2019).

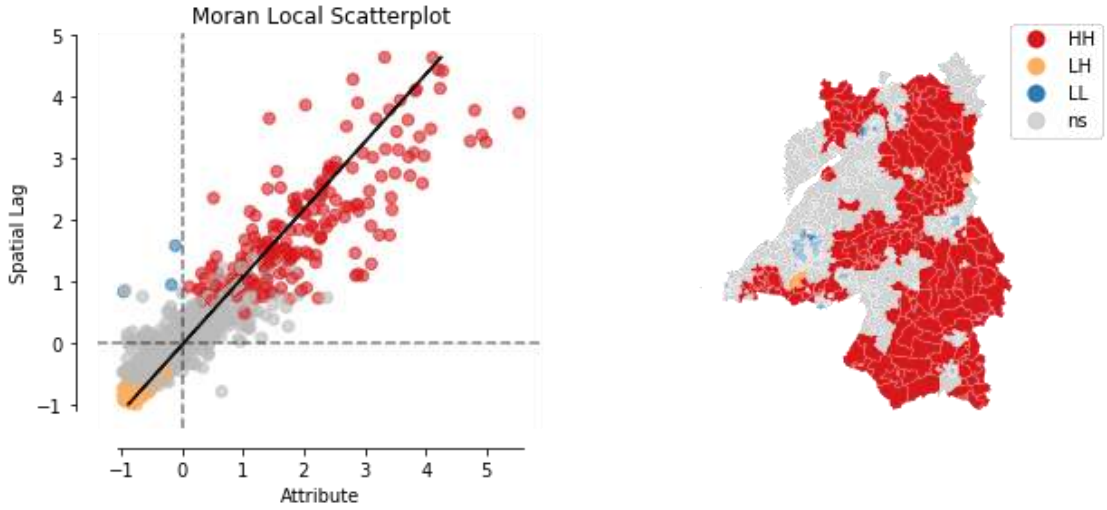
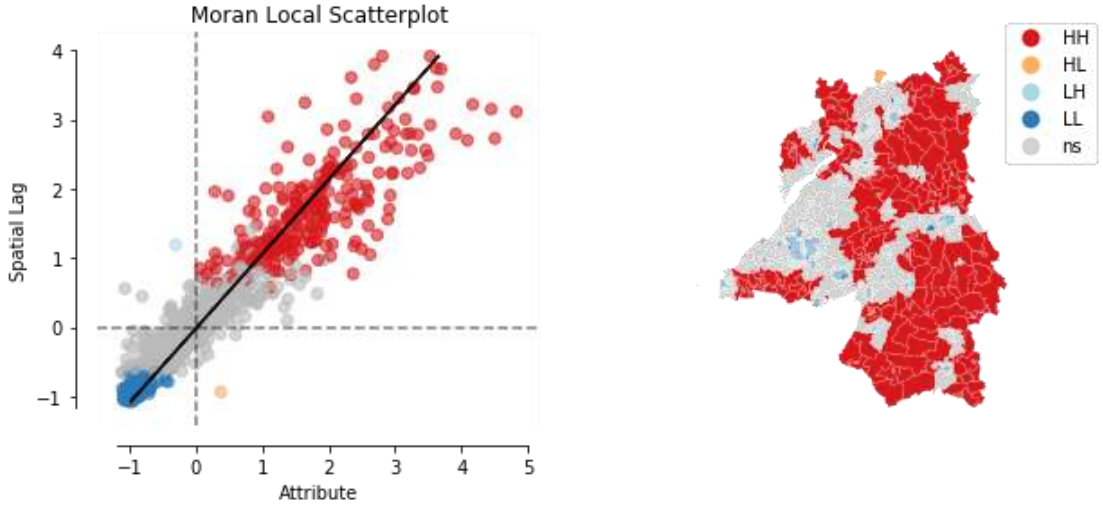


Figure 20: UKK1 NUTS2 Area. Gloucestershire, Wiltshire and Bristol/Bath Area. Moran I and LISA clusters for distance to the second closest branch (Distance 2, February 2019).



These measures indicate a **very strong spatial autocorrelation for both Distance 1 and Distance 2 for branches**.

In order to identify local clusters for Distance 1 and Distance 2, we calculated *local* indicators for spatial association (LISA). The LISA map in Figure 19 shows a large High-High cluster (in red) which expands in Figure 20. The red and blue 'spatial clusters' correspond to the red and blue points in the left-hand side scatterplots. The expansion of the red area as new zones join the High-High cluster. **These figures now show that more areas depend on one single branch (the one currently the closest).**

Could these areas have been identified in advance by using the LISA map for Distance 2 or by calculating the Impact Index? Knowing that in this region eleven branches have closed between February - July 2019, we compare Distance 1 for branches measured in February 2019 with the same distance measured in July 2019 (Figure 21). We observe that the closures did not change the map layout of Distance 1 for branches. This means that these closures happened either in areas where there were other branches as well, or, that the distance to the branch which now becomes the closest to the centroid of each small statistical area, remains within the same distance bracket (i.e. less than 500m, 1000m, etc.). However, if we compare Distance 2 for the same period, we notice that there are changes. The red and blue circles in Figure 22 for Distance 2 for July 2019 show areas which moved above the Impact Index 4 threshold. These areas appeared in the LISA High-High cluster in Figure 20 as well. This shows that we can identify the vulnerable areas both through local spatial indicators (LISA) for Distance 2 or the Impact Index.

The four maps in Figure 21 show that while the branch closures between February - July 2019 in this region do not have an immediate impact in terms of access, they increase the vulnerability of some areas by leaving them dependent on one branch.

5.6. The Void

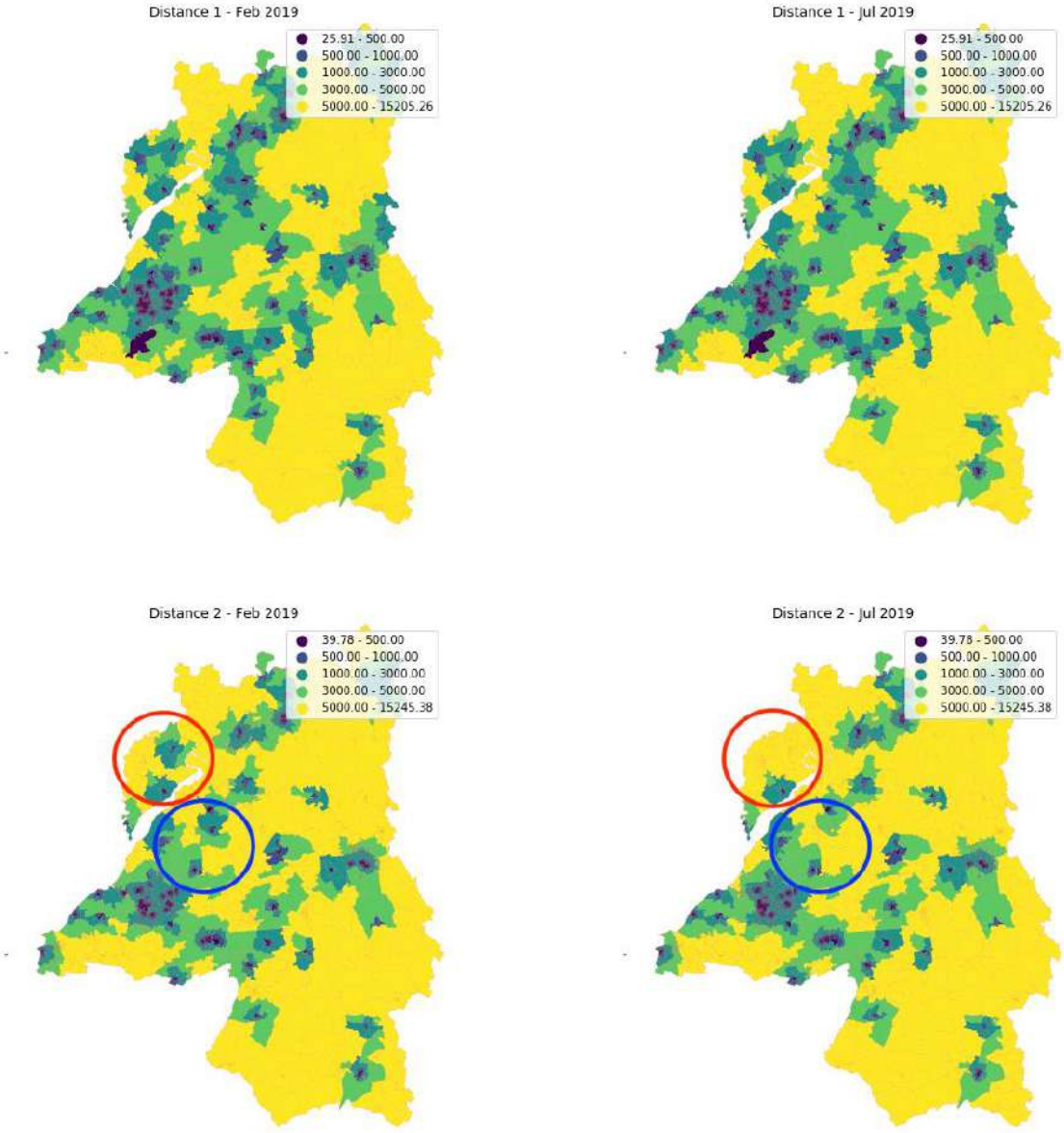
A quantitative definition of "the Void" is not yet established. However, we explored the following combinations:

(1) a small statistical area identified as "Constrained by Infrastructure" and for which the distance from the centroid of the area to the first physical infrastructure point is larger than 3000m. (Figure 19).
(2) a small statistical area identified as "Constrained by Infrastructure" and for which the distance from the centroid of the area to the closest branch is larger than 3000m. (Figure 20).
(3) a small statistical area for which the distance from the centroid of the area to the first physical infrastructure point is bigger than 3000m and a high proportion of the premises cannot get fixed broadband over 2Mbs (Figure 21).

This last category does not account for mobile broadband, but the data about the availability and quality of fixed broadband is more recent. We note again that if we were to consider the Universal Standard Obligation threshold for "good internet", more areas would appear as underserved.

At the UK level, if we use the 5000m threshold for Distance 1 for all physical infrastructure points, and the 20% threshold for the proportion of household that cannot get 2Mbs, we find that only 62.661 people live in such areas. Out of these, 35.785 are in Scotland, 14.424 in England, 10.645 in Northern Ireland and 1.807 in Wales. If we combine the same distance threshold with the "constrained for infrastructure" category, we find that 67.111 people in England live in such areas. The large differences in the size of the population affected, tells us once more that the banking industry needs to find good measures for estimating the quality of the broadband. After all, the delivery of their digital channels depends on it.

Figure 21: Gloucestershire, Wiltshire and Bristol/Bath areas. Distance to the closest branch (Distance 1) and distance to the second closest branch (Distance 2). A comparison between February and July 2019.



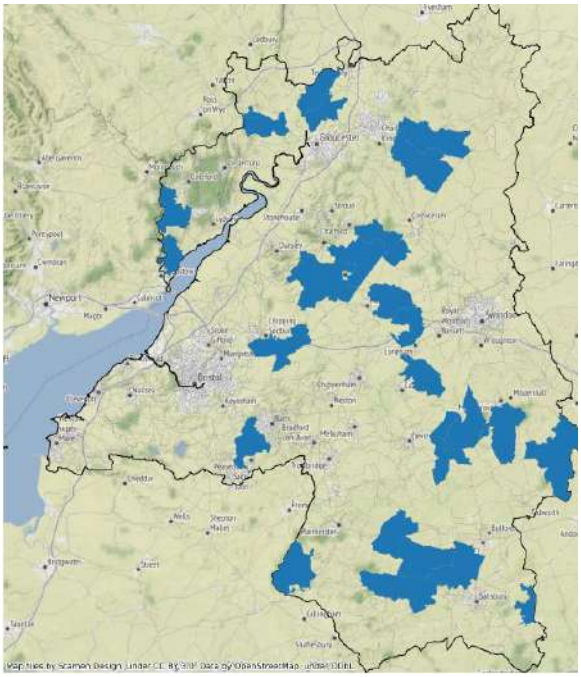
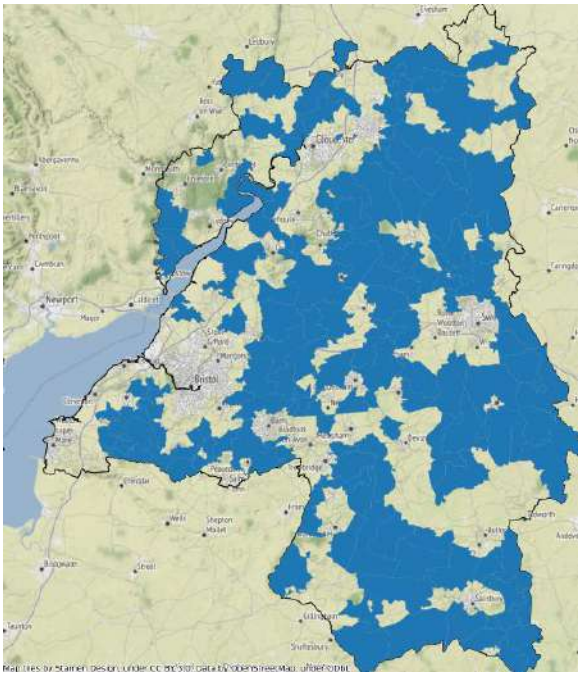
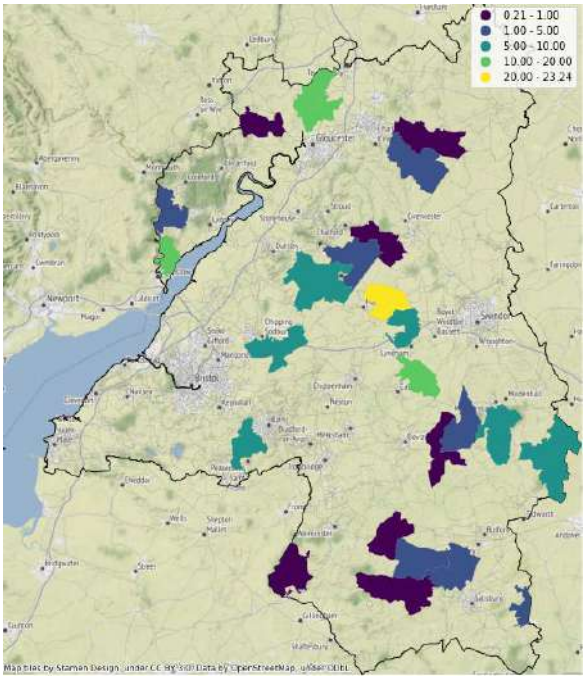


Figure 22: (left) Gloucestershire, Wiltshire, and Bristol/Bath areas (NUTS2 : UKK1). "The Void" – The distance to the closest point of physical infrastructure is bigger than 3000m (Feb 2019) and Internet User Classification of the area is “Constrained by Infrastructure”.

Figure 23: (below left) Gloucestershire, Wiltshire, and Bristol/Bath areas (NUTS2 : UKK1). "The Branches Void" - The distance to the closest branch is bigger than 3000m (Feb 2019) and Internet User Classification of the area is “Constrained by Infrastructure”.

Figure 24: (below right) Gloucestershire, Wiltshire, and Bristol/Bath areas. The distance from the centroid of the area to the first physical infrastructure point is bigger than 3000m (Feb 2019) and a proportion of the premises cannot get fixed broadband over 2Mbs (2017).





6. Limitations and Future Directions

6.1. Limitations

Most of the current limitations of this study come from data scarcity or accuracy. Three aspects are particularly important:

- None of the datasets for points of access (ATMs, branches, Post Office) can be retrieved regularly and accurately from open data sources.
- Broadband data availability and quality is old and at too high level.
- The methodology for calculating socio-economic variables differs across the UK countries.

Post Office Network. The capability and capacity of the Post Office network cannot be established based on the location data made available by the post office. This is important for measuring access because the post office network is larger in spatial spread than the network of banking and building society branches[34]. As discussed before, outreach post offices do not have the same capability and capacity as the Crown and agency offices or full-time physical banking branches. This might falsely indicate high access for an area when it is not the case.

Banking and building societies branches. The accuracy of the data provided through Open Banking APIs occasionally renders the data unusable. Many mobile branches were mislabelled as physical, there were duplicate branches, missing geographical co-ordinates and sometimes inaccurate information about these points of access (i.e. identification codes, sort codes, services provided). Apart from the banks mandated to provide Open Banking APIs for branches and products, very few other banks have independently adopted these particular industry standards.

Non-bank ATM acquirers seem to be under no obligation to publish the location and the fees of their ATMs. As they provide more than 70% of the UK ATMs, this makes it difficult to accurately monitor the coverage.

Fixed and mobile broadband. As digital banking is adopted by preference or necessity, the retail banking industry increasingly relies on the telecom network. Accurate, granular data about the availability of fixed and mobile broadband is required in order to be able to assess access to digital banking, and to build an access measure which includes access to both physical and digital channels. Such data is not currently openly available. On a practical note, the lack of accurate, granular information about their own customers' access to broadband is critical to banks. The Regulatory Technical Standards (RTS) of the Payment Services Directive 2 (PSD2) require customers to authenticate financial transactions through security tokens which they should be able to receive by e-mail, by text or in the mobile app. This is not possible in areas where the customer does not have sufficient access to the network.

For the **socio-economic characteristics**, we have only used the income and employment components of the Index for Multiple Deprivation for the UK. We did this because most of the other characteristics that would have been relevant were calculated in relative terms by the devolved statistical bodies for each UK country, and the values and methods were not comparable at a UK level.

This UK level analysis allows us to identify regions for further focus of studies within this domain. However, the scale of analysis, and the diverse geography and

[34] There are 11500 post office and 7348 physical branches (February 2019).

economic conditions across the UK, did not allow us to develop an explanatory model for the dynamics observed.

6.2. Future Directions

For this study, we used spatial centroids and straight-line distance measurements. For future studies, we plan to focus on **smaller regions, and use population weighted centroids and street network distance calculations**.

Given the different geography of each country, especially that of Scotland and Northern Ireland, we believe that each country should be studied individually, while maintaining compatible, and in turn, comparable methods.

We learned that **the geographical presence of a point of access does not indicate full access,** as there is a wide variability in terms of capacity and capability across access points. We would like to re-run the analysis using accurate information about the capability and capacity of the post offices.

The availability and quality of fixed and mobile broadband requires assessment for the area affected by closure. Where blackspots of broadband are identified, it is worth a further inquiry into the socio-economic characteristics of the area or even at the Internet User Classification, in order to estimate **how the respective population is likely to be affected**.

We would like to continue our research beyond this initial exploratory study as follows:

(1) continuous mapping of the retail banking infrastructure;

(2) separate analysis of access to banking for Scotland, Northern Ireland and Wales;

(3) validation of the “North/South divide” identified by Arcaute et al. (2016) as applied to access to banking;

(4) contribution of mobile branches and outreach post offices to access retail banking services;

(5) in-depth analysis of the regions studied using socio-economic characteristics like car-ownership, public transport availability, as well as detailed components of the Index for Multiple Deprivation.

7. Conclusions

Our exploratory study establishes the basis for further in-depth understanding of the infrastructure of access to retail banking and for the development of measures for "access".

7.1. UK maps of access to financial services

We identified and collected data to map the access to financial services and highlighted the limitations the industry experiences in terms of availability and accuracy of the data. Building a "map of the range of channels through which the consumers can access cash (e.g., bank and building society networks, post offices, ATMs, merchant cashback, etc.)"[35] is one of the commitments of UK Finance in response to the Ceeney Review.

The lack of clarity on the capacity and capability of the Post Office is a risk for the industry. If the industry were to rely on post offices when closing branches, they would have to ensure the viability of the remaining infrastructure. Furthermore, the recent Post Office Inquiry highlights the pressure that the post offices are under, in order to provide basic banking services[36] (Post Office Network Parliamentary Inquiry, 2019).

7.2. Spatial patterns

At a UK level, we found **strong spatial patterns** of clustering for "access" to physical retail banking infrastructure, measured as the Euclidian distance from small statistical areas to these points. The **urban/rural separation** is clear, as was expected given the different population densities of these areas.

At this stage, we did not find strong associations between the socio-economic characteristics of the areas and "access" in the way we measured it. While it is common in the press to state that the points of access (ATMs and branches) close predominantly in the most economically deprived areas, this is not what we observed for the branch closures in the past six months or even for the overall state in February 2019.

We believe that the **number of branches of a bank might be a stronger predictor of which branches will close in an area**. We observed that financial institutions have a very different spatial footprint in the UK[37]. Some have a national footprint, others a regional one, while others like Metro are only present in busy urban areas. The reasons for opening or closing branches are very different for a bank that has 100 branches compared to one that has 1000 branches. They have more to do with the bank than with the areas themselves. In the context of a rapidly changing infrastructure landscape, **banks might feel the pressure to close branches faster in unprofitable areas, so that those branches are not the only points remaining. This way they could avoid further pressure to maintain them.**

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[35] UK banking and finance industry commits to support local communities' free access to cash | UK Finance (2019)

[36] Kelly Tolhurst, MP stated that under the current "Banking Framework", "for every £8,000 [deposits taken], the postmasters are getting £3.12", but she could not confirm how much the banks are paying the Post Office for these services (Tolhurst MP, 2019).

[37] See Appendix 2: Number of physical and mobile banking branches by brand, UK (February 2019) and Figures 5 and 6 for examples of two banks' branches spatial spread.

7.3. Indicators of access

We have identified the following indicators of access for physical banking channels:

- **Distance 1**: shortest distance from the centroid of an area to the closest physical point of access to financial services (ATM, branch, post office)
- **Distance 2**: shortest distance from the centroid of an area to the second closest physical point of access to financial services (ATM, branch, post office)
- **Impact Index**: the difference between Distance 2 and Distance 1 for the same period, identifying the degree of vulnerability of an area to the closure of the closest points of access.

Each of the indicators above can be calculated for a single point of access or for all of them together as one system.

In a rapidly changing infrastructure landscape, we use Distance 1 to characterise the current state of access. We use Distance 2 and the Impact Index to identify the vulnerability of an area to the closures of specific points of infrastructure.

As a **proactive measure for maintaining essential territorial coverage, we believe that the regulators should watch the measurements of Distance 2 and the Impact Index** when monitoring closures. Both are "easy-to-apply"" measures for identifying: 1) the areas that depend on one point of access, and 2) the very important points of access that ideally should be preserved.

We draw attention to the **capacity** and **capability** of each physical access point and the impact they have on developing a comprehensive local indicator for access to financial services. We believe that separate maps should be developed for different types of services (i.e. a map of ATMs that are accessible and can deliver £5 notes; a map for "cash deposits" facilities, etc).

In order to assess access to digital channels, we used the following indicators:

- The percentage of premises not able to receive fixed broadband data at or above 2MBs;
- The "constrained by infrastructure" category of Internet User Classification (2014).

These are imperfect indicators and we hope that, as more detailed data will become available, we will be able to define more specific indicators for measuring access to digital banking channels.

Even so, they can be used in conjunction with the indicators for physical access in order to identify areas with reduced access to both physical and digital banking channels.

7.4 The Void

"The Void" as defined in this study, is an extreme situation for which a quantitative definition does not yet exist. What is more important than the "Void's" quantitative parameters, is how individuals experience such contexts. This is likely to depend on individual socio-economic characteristics. Such an analysis was not part of this study.

Our regional analysis for Gloucestershire, Wiltshire and Bath/Bristol areas showed that the most "extreme situation" was a small area with a population of 1500 people where the closest point of infrastructure was an ATM at over 3700 km distance from the centroid of the area. In this area, 20% of the population could not have fixed broadband of at least 2MBs from any provider. There are other areas experiencing either reduced access to physical infrastructure or digital services, but only this isolated area in Gloucestershire, Wiltshire and Bath/Bristol experienced both. However, these parameters, would be the norm in Scotland.

7.5. Infrastructure Ownership

Last but not least, it was obvious to us that in the UK it is not the case anymore that the majority of endpoints of the infrastructure for access to banking belong to the banks themselves. There are more post

offices than the overall banking and building societies branches. 98% of the post offices are private businesses and only 2% are Crown offices. Over 70% of the ATM locations are not operated by banks. Access to digital banking depends on the telecom infrastructure and on the ability of the individuals to acquire and use a smartphone.

Finance is considered as one of the thirteen sectors of National Critical Infrastructure[38]. Hence, much like other critical infrastructures, one must be able to model it in order to ascertain robustness and resilience parameters. Water and electricity infrastructures, for example, have well-maintained models in order to accurately prepare for all forms of disruption as well as to provide insight for future expansion. Consider the potential closure of 2500 post offices, as projected by the National Federation of Subpostmasters. What would that entail for access to retail banking? What is the projected impact on retail banking of a regional outage of the telecom infrastructure? Such questions can only be quantitatively answered if one comprehensively models the infrastructure on which finance depends. The points of access to retail banking are of course just one layer of this infrastructure.

[38] Critical National Infrastructure | CPNI | Public Website (n.d.)

8. Recommendations

1. **Measurement of access to physical and digital banking channels is possible** despite current data limitations. Industry players should be able to apply the same methods in order to quantify the local impact of planned closures.
In parallel, we recommend further exploration of measures of access, which take into consideration access to both physical and digital channels.

2. Our conclusions support the Ceeney Review recommendations. More specifically, we show that the **access points to retail banking need to be treated as a "joined-up" system** if we want to understand access, and assess territorial coverage. Without complete, accurate information, different players may withdraw from the same areas unknowingly, leading to a large regional impact for the communities affected. As the Ceeney Review shares from the Swedish experience: "once [the] infrastructure had gone, putting it back was close to impossible".

3. We go further in our recommendation by saying that **not only the cash infrastructure should be considered as one system, but the telecom infrastructure required for accessing online and mobile banking should be considered too** if we look at enabling digital payment methods. The telecom infrastructure enables not only customers but also merchants to operate digitally.

4. We recommend **more transparency from all retail banking players in making accessible data about the locations, and the capability and capacity of the points of access.**

The Post Office Network, a public entity which plays a safeguarding role when banking branches close, does not have APIs for its office locations, akin to the banks which have a much smaller physical presence in the UK (i.e. Danske Bank, FTNI, Nationwide). The continuously changing capacity and capability of the network can be assessed if one regularly web-scrapes their website.

The same is true for the other smaller players - banks or ATM providers. **The Open Banking APIs for Branches and ATMs will become very useful when extended to all providers.** Only when the standard will allow the creation of a real-time trusted image of the retail banking points of access, we will see these APIs incorporated in third party digital platforms and thus bringing value to customers.

The quality of the Open Banking API data varies. Very often, the APIs do not deliver current data but something more akin to an old file download. The APIs provide the regular schedule of a branch but would not show if, as an exception, a certain branch is closed at the time of running the API. The aims of having these APIs should be reviewed to ensure they provide meaningful value to the potential users.

The dynamic access points mapping is important, because their closure is a gradual, continuous process. The commercial entities involved have valid and diverse reasons for closing. When there are no commercial incentives for staying open (we see gaps appear in the network), one has to re-think how fair access should be maintained for all. "We need to start considering cash to be a core part of Britain's national infrastructure, and not just as a commercial issue." (Ceeney, 2019, p. 7). **The management of any type of national infrastructure requires its modelling and this is not possible without data.**

5. Equally, we recommend **more transparency from the telecom providers on the quality of fixed and mobile broadband.** Digital banking, which shows significant year over year

growth, depends on the availability of the telecom infrastructure.

Without granular data for mobile and fixed broadband availability and quality, the industry cannot see whether their customers can indeed access their digital channels in case they decide to close points of physical access.

6. We recommend further study on how the mobile branches and outreach post offices work as a channel and how the communities are impacted by it. Special attention should be paid to people with limited mobility or in economically vulnerable situations.

Apart from sometimes being open only five minutes per week, the mobile branches and outreach offices offer substantially less services compared to normal branches and post offices. Therefore, measures of access should take into consideration both the capability and capacity of a point of access.

The planned expansion of 5G could potentially target areas with reduced access to financial services. This could be aligned with the Ceeney Review recommendation “to make digital inclusion in payments a priority” (Ceeney, 2019, p. 7).

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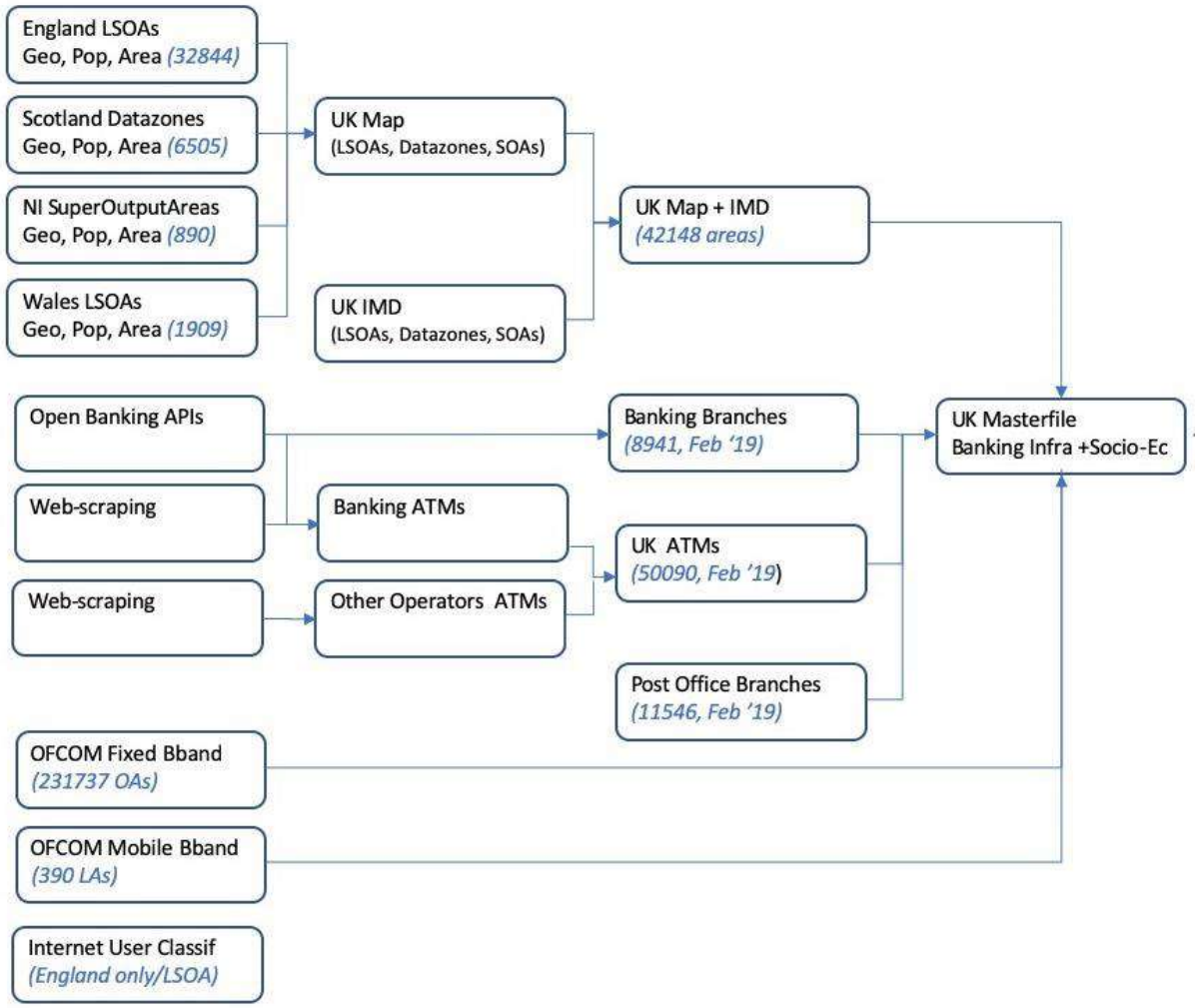
10. Appendix

Appendix 1: Data Sources



Appendix 2: Number of physical and mobile banking branches by brand, UK (February 2019)

Bank	Physical Branch	Mobile Branch
Barclays[39]	1143	
Lloyds Bank	957	114
Natwest + Natwest Offshore[40][41]	861	432
Santander UK PLC	754	
Nationwide Building Society	676	
HSBC UK	636	
Halifax	612	
TSB	558	
Bank of Scotland	207	108
Royal Bank of Scotland	144	939
Yorkshire Building Society	97	
Skipton Building Society	87	
Virgin Money	76	
Clydesdale Bank	70	
Coventry Building Society	70	
Co-op	69	
Metro	65	
Leeds Building Society	63	
Danske Bank	46	
West Bromwich Building Society	37	
Bank of Ireland	30	
M&S Bank	29	
Coutts	22	
AIB	16	
First Trust Bank	15	
Total	**7348**	**1593**

[39] The Gibraltar Branch Barclays Bank is included here, but excluded in the spatial calculations of this study.

[40] Natwest Open Banking API returns two brands: Natwest and Natwest Offshore. Natwest Offshore branches are, however, 100% based on UK territory. Where their location perfectly overlaps with another Natwest Branch, we eliminated the Natwest Offshore branch to avoid double counting of branches. This was the case for 648 branches which appeared twice, both as Natwest and Natwest Offshore branches. The number of 861 is made out of 656 Natwest and 205 Natwest Offhsore Branches.

[41] All the Natwest Mobile Branches belong to the Natwest brand.

Appendix 3: Number of ATMs Locations by ATM Acquirer, UK (March 2019)

ATMs Acquirers	Number of ATMs Locations
Cardtronics UK Ltd	13586
NoteMachine Ltd	9923
Paypoint	3774
Royal Bank of Scotland	2946
YourCash ATM Systems Ltd	2880
DC Payments UK LTD	2620
Bank of Ireland	2428
Barclays Bank UK plc	2272
Sainsburys Bank	1456
Omnicash	1408
National Westminster Bank/NatWest	1010
Lloyds Bank Plc	914
Santander UK	803
Nationwide Building Society	749
HSBC UK Bank plc	674
Halifax plc	644
TSB Bank	491
Travelex UK Ltd	357
Bank of Scotland	208
Yorkshire Bank plc	182
RAPHAELS BANK	175
Northern Bank Ltd	146
Clydesdale Bank plc	137
Ulster Bank	136
Moneycorp CFX Ltd	101
AIB Group (UK) plc	58
Coventry Building Society	47
ChangeGroup ATMs Ltd	43
Cumberland Building Society	20
G4S Cash Solutions UK Ltd	2
TOTAL	**50190**

Appendix 4: Access Criteria for the Post Office (Brown & Booth, 2018)

- 99% of the UK population to be within three miles of their nearest post office outlet;
- 90% of the UK population to be within one mile of their nearest post office outlet;
- 99% of the total population in deprived urban areas across the UK to be within one mile of their nearest post office outlet;
- 95% of the total urban population across the UK to be within one mile of their nearest post office outlet;
- 95% of the total rural population across the UK to be within three miles of their nearest post office outlet.
- 95% of the population of every postcode district to be within six miles of their nearest post office outlet.

Appendix 5: Total population and proportion of population over 65 in the areas where the Distance 1 and Distance 2 are bigger than 5000m

Country	Population total	Areas where Distance 1 > 5000m				Areas where Distance 2 > 5000m			
		Total Population		Population over 65		Total Population		Population over 65	
		nr of people	%	nr of people	%	nr of people	%	nr of people	%
	a	b	b/a	c	c/b	d	d/a	e	e/d
England	55619430	94383	0.17%	24791	26.27%	691490	1.24%	175592	25.39%
NI	1870836	19417	1.04%	3125	16.09%	163129	8.72%	26398	16.18%
Scotland	5425291	127944	2.36%	29569	23.11%	388672	7.16%	90483	23.28%
Wales	3125165	33536	1.07%	9373	27.95%	136534	4.37%	36344	26.62%
TOTAL	**66040722**	**275280**		**66858**		**1379825**		**328817**	

Appendix 6: Branches Openings - Jan - July 2019

Bank	Type of Branch	Jan-19	Feb-19	Apr-19	Jun-19	Jul-19	Total
Bank of	Physical						0
Scotland	Mobile				1	3	4
Barclays	Physical	7					7
LBG	Physical	9	4	1		1	15
	Mobile	21	7			1	29
Total	Physical	16	4	1	0	1	22
	Mobile	21	7	0	1	4	33
TOTAL		**37**	**11**	**1**	**1**	**5**	**55**

Appendix 7: Descriptive statistics for income as a component of Index of Multiple Deprivation for UK

Area	All/Subset	nr statistical areas	mean	std	min	25%	50%	75%	max
UK	**All UK**	42149	14.76	10.50	0.00	6.6	11.8	20.6	90.00
England	**All England**	32844	14.52	10.31	0.50	6.50	11.40	20.20	63.90
England	**Distance_1>5000m**	56	6.84	2.84	2.40	4.90	6.00	8.03	16.60
England	**Distance_2>5000m**	404	7.85	3.97	0.80	5.10	6.90	9.60	37.70
NI	**All NI**	890	25.20	15.55	0.00	13.25	22.00	33.00	90.00
NI	**Distance_1>5000m**	7	16.29	4.99	9.00	12.50	18.00	20.00	22.00
NI	**Distance_2>5000m**	70	20.10	7.66	5.00	16.00	19.00	26.75	35.00
Scotland	**All Scotland**	6506	13.78	9.81	0.00	6.00	11.00	20.00	65.00
Scotland	**Distance_1>5000m**	160	7.54	3.41	1.00	5.00	7.00	9.00	19.00
Scotland	**Distance_2>5000m**	482	8.11	4.32	1.00	5.00	7.00	10.00	30.00
Wales	**All Wales**	1909	17.31	10.10	2.00	9.00	15.00	23.00	69.00
Wales	**Distance_1>5000m**	19	9.11	2.71	5.00	7.00	9.00	10.50	14.00
Wales	**Distance_2>5000m**	82	10.12	3.69	4.00	8.00	9.00	12.00	22.00

Appendix 8: Descriptive statistics for employment as a component of Index of Multiple Deprivation for UK

Area	All/Subset	count nr statistical areas	mean	std	min	25%	50%	75%	max
UK	**All UK**	42149	12.23	7.90	0.00	6.2	10	16.4	73.00
England	**All England**	32844	11.91	7.68	0.3	6.2	9.7	15.8	58
England	**Distance_1>5000m**	56	6.20	2.60	2.3	4.45	5.35	7.9	13.8
England	**Distance_2>5000m**	404	7.02	3.30	0.5	4.7	6.3	8.7	31
NI	**All NI**	890	13.16	6.13	0	9	12	16	42
NI	**Distance_1>5000m**	7	9.71	1.60	8	8.5	9	11	12
NI	**Distance_2>5000m**	70	11.46	3.16	4	9	12	13.75	19
Scotland	**All Scotland**	6506	13.32	9.12	0	6	11	19	73
Scotland	**Distance_1>5000m**	160	7.21	3.01	2	5	7	9	16
Scotland	**Distance_2>5000m**	482	7.79	3.95	1	5	7	10	29
Wales	**All Wales**	1909	13.45	7.42	2	7	12	18	60
Wales	**Distance_1>5000m**	19	7.05	2.25	4	5.5	7	9	12
Wales	**Distance_2>5000m**	82	7.59	2.88	3	6	7	9	17

Appendix 9: Online Appendix

Data collection: Andra Sonea (PhD Candidate, University of Warwick), Mohamed Mahdi (Software Engineer), Andrei Sonea (student, King's College London)

Data accessibility: Data is available at Zenodo:
https://doi.org/10.5281/zenodo.3417103

Code: https://github.com/andrasonea/TFI_AccessToBanking
The analysis was undertaken using Python 3.6.[42] QGIS 3.4.[43] and Geoda 1.10.[44]

[42] Rey & Anselin (2007); Plotly Technologies Inc., (2015); Arribas-Bel (2019); McKinney et al. (2010)

[43] QGIS Development Team (n.d.)

[44] GeoDa: An Introduction to Spatial Data Analysis —Anselin — 2006 — Geographical Analysis — Wiley Online Library (n.d.)

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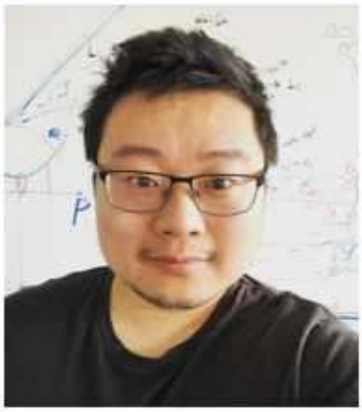

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