Geoforum 69 (2016) 5–18

Contents lists available at ScienceDirect

Geoforum

journal homepage: www.elsevier.com/locate/geoforum

Measuring the spatial vulnerability of retail centres to online consumption through a framework of e-resilience

A.D. Singleton[a,*], L. Dolega[a], D. Riddlesden[a], P.A. Longley[b]

[a] Department of Geography and Planning, University of Liverpool, Roxby Building, Liverpool L69 7ZT, UK
[b] Department of Geography, University College London, Pearson Building, Gower Street, WC1E 6BT, UK

ARTICLE INFO

Article history:
Received 5 August 2015
Received in revised form 14 November 2015
Accepted 18 November 2015
Available online 11 December 2015

ABSTRACT

This paper presents e-resilience as a framework for assessing the extent to which retail centres have spatially differentiated vulnerability to the impacts of online consumption. This extends the conceptual model of resilience as applied to retail, and is operationalised through a novel methodology that develops two indices that balance both supply and demand influences. We describe the creation of a composite e-resilience indicator, and then calculate it for retail centres across England. Our findings suggest a geographic polarising effect, with least vulnerable centres identified as large and more attractive or as smaller local destinations with a focus on convenience shopping. Mid-sized centres were typically shown to be the most exposed, and are argued as having a less clearly defined function in contemporary retail. Such findings have wide policy relevance to stakeholders of retail interested in the future configuration of sustainable and resilient provision.

1. Introduction and background

UK Government initiatives aimed at revitalisation of British high streets (Portas, 2011; Digital High Street Advisory Board, 2015) highlight the importance of digital technology in redefining traditional retail spaces. Evidence suggests that growth in online consumption impacts upon the health of retail centres in complex ways (Weltevreden, 2007), and can be viewed as a source of long-term change to their structure, often referred to in the literature as a 'slow burn' (Pendall et al., 2010). Adjustments to the market share of traditional town centre retailing have been mainly considered with respect to their supply side effects: for example, the extent to which online shopping has substituted, modified or complemented traditional town centres (Weltevreden, 2007; Doherty and Ellis-Chadwick, 2010). However, there has been less focus on how the structure of traditional high streets are or might be impacted by consumer propensity for online shopping, how such effects could be modelled, or what might be an appropriate adaptive response by stakeholders in retail. Despite evidence to suggest that factors impacting decisions about whether or not to shop online are linked to demographic and socio-economic characteristics of populations (Longley and Singleton, 2009), we nevertheless posses limited knowledge about the geography of online sales (Forman et al., 2008).

This paper explores these challenges through developing the concept of *e-resilience*, which provides both a theoretical and methodological framework that defines the vulnerability of retail centres to the effects of rapidly growing Internet sales, balancing characteristics of both supply and demand. We argue that the concept of e-resilience adds value to existing research in the following ways:

(i) It provides insight into wider debates on the performance of UK town centres in the rapidly transforming retail landscape, in particular by assessing their resilience and adaptability to the growth of online sales.
(ii) It provides insight into demand through examination of local catchment demographics, and thus rebalances current debates on the resilience of high streets, which hitherto have predominantly focused on supply effects, measured through outcomes such as retailer failures or vacancy rates.
(iii) It delivers valuable outputs including: an operational measure of e-resilience, which is implemented to define those retail centres in England that are the most or least e-resilient.
(iv) It presents a national geodemographic of Internet user behaviour. It is anticipated that such outputs will be of interest to a wide range of stakeholders in retail policy and provision.

The general concept of resilience has been established for some time to describe how various types of system respond to

* Corresponding author.
E-mail address: alex.singleton@liverpool.ac.uk (A.D. Singleton).

http://dx.doi.org/10.1016/j.geoforum.2015.11.013
0016-7185/© 2015 The Authors. Published by Elsevier Ltd.

unexpected shocks. There are three widely recognised concepts of resilience adopted between different scientific traditions (Simmie and Martin, 2010): (a) the engineering resilience interpretation found in physical sciences; (b) the ecological resilience interpretation found in biological sciences; and (c) the adaptive resilience interpretation found in complex systems theory. The first two interpretations refer to the notion of equilibrium, which suggest that a resilient economic system would adapt successfully to disturbance and either resume, or even improve its long-run equilibrium growth path. Conversely, a non-resilient system would fail to transform itself successfully and instead become 'locked' into a long-run outdated trajectory or decline (Simmie and Martin, 2010; Dawley et al., 2010). The third interpretation, identified by Martin (2011) as 'adaptive resilience', stresses the anticipatory or reactive reorganisation of the form and function of a system to minimise the impact of a destabilising shock, and focuses on resilience as a dynamic and evolutionary process. Complex system theory is characterised by non-linear dynamics and self-reinforcing interactions among a system of components (Martin and Sunley, 2007), and highlights self-organisation, with adaptive growth relative to changes in the external environment (e.g. the impact of online sales on traditional retailers).

Increasing numbers of social scientists have also begun to use resilience as a mechanism to help explain the impact and response to disruptions and more gradual processes of change in a range of socio-economic systems (Christopherson et al., 2010; Pendall et al., 2010; Hassink, 2010; Simmie and Martin, 2010; Martin, 2011). For example, resilience was first considered within the context of the UK high street by Wrigley and Dolega (2011), who investigated the dynamics of performance and adjustment to the shock of the global economic crisis. In this work they rejected the notion that town centres and high streets could return to their pre-shock configurations, and developed the concept of "adaptive resilience" whereby the resilience of UK town centres was viewed as a dynamic and evolutionary process. More specifically, they argued that the response of UK town centres to economic and competitive shocks can be seen as a function of the mix and interdependencies of existing business, the dynamics of centres, diversity, attractiveness, accessibility, national planning policies and the socio-demographic characteristics of local catchments. Such characteristics and actions are responsible for building town centre adaptive capacity. Often an economic or competitive shock creates new opportunities for development and innovation (Pendall et al., 2010; Raco and Street, 2012) which, in turn, leads to the emergence of more adaptable town centres characterised by enhanced resilience and ability to more effectively withstand future disturbances. The resilience framework strengthens some basic arguments derived from evolutionary economics such as the advantages of diversity, seeing regional economies as path-dependent systems (Hassink, 2010), or the potential of novelty and selection in economic systems as they adjust to evolving circumstances (Simmie and Martin, 2010). Furthermore, Dolega and Celinska-Janowicz (2015) argue that future resilience of town centres is crucially dependent upon recognising and acting upon the challenges arising from current trends. A good example of such pre-emptive action in the UK was the establishment of the Digital High Street Advisory Board in 2014 to provide an independent assessment of strategies to revitalise high streets in the context of a digital future.

Equally important to retail centre resilience is an understanding of the geodemographic characteristics of local catchments (Birkin et al., 2002), as consumer choices and behaviours are fundamental drivers of demand, and therefore are closely related to evolution of the retail landscape. Importantly, the behaviours and attitudes of consumers vary spatially, yet are directly linked to the geography of demand for retail facilities. Understanding the geography of consumer behaviour (such as varied propensity for online shopping) at a small area level is crucial to understanding the vitality and viability of both retail centres and the retailers themselves. Indeed, the resilience of retail centres is intertwined with the underlying dynamics of their catchments as variations in consumer confidence (Wrigley and Dolega, 2011) and basic digital skills (Digital High Street Advisory Board, 2015) are likely to shape demand for retail spaces in the digitally transformed retail landscape. The current debate on economic health of UK town centres seems to acknowledge the key role consumers have in that transformation, and a direct response of retail spaces to consumers' needs is being perceived as key to their success (DCLG, 2013).

2. A framework to understand and measure e-resilience

The Internet enhances opportunities for price comparison, enables 24/7 convenience, provides a selection of products not limited by physical space, and enables distribution with a wider geographical reach (Williams, 2009). As such, it is perhaps unsurprising that online sales have been growing exponentially; essentially tripling over the past eight years, and are forecasted to reach 15.2% of all UK retail sales by the end of 2015 (Centre for Retail Research, 2015). Furthermore, in recent years, there has also been a shift towards using mobile devices for online shopping, such as tablets and smartphones, which are now estimated to account for the majority of growth in UK online retail sales (Capgemini, 2015). In consequence, the rapid expansion of online shopping has been increasingly viewed as a major cause of change to the structure of traditional UK high streets (Digital High Street Advisory Board, 2015; Wrigley and Lambiri, 2014). Weltevreden (2007) investigated the implications of e-commerce on traditional physical shopping space, and established the extent to which online retailing could be associated with processes of substitution, complementarity, and modification of traditional retail channels. Substitution occurs when e-commerce replaces physical shopping; however, complementarity and modification pertain to a blending of e-commerce with traditional retailing. These latter two omni-channel processes are however, less well understood (Wrigley and Lambiri, 2015; Weltevreden, 2014). For instance, in the UK a number of national retailers such as Borders, Zavvi, Jessops and Game have either entirely withdrawn or substantially limited their physical retail offerings within the past few years, while some other major retailers such as John Lewis, Next, Boots or Argos have successfully embraced new technologies through opening 'click and collect' points, or by developing mobile applications (Turner and Gardner, 2014).

The basic concept of e-resilience defines the vulnerability of retail centres to the effects of growing Internet sales, and estimates the likelihood that their existing infrastructure, functions and ownership will govern the extent to which they can adapt to or accommodate these changes. Essentially, e-resilience can be expressed as a balance between the propensity of localised populations to engage with online retailing and the physical retail provision and mix that might increase or constrain these effects, as not all retail categories would be equally impacted. However, estimating the interaction between potential consumers and retail destinations is increasingly complex. For example, there is emerging evidence that choice is related to both experiential factors (Wrigley and Lambiri, 2014; Shobeiri et al., 2015) and a provision of a broader range of services, technologies and activities within shopping localities (Hart and Laing, 2014; Digital High Street Advisory Board, 2015). Although some of these factors may be difficult to quantify for a national extent, empirical evidence suggests that presence of anchor stores and various service providers (typically those difficult to digitise) such as leisure, are associated with lower

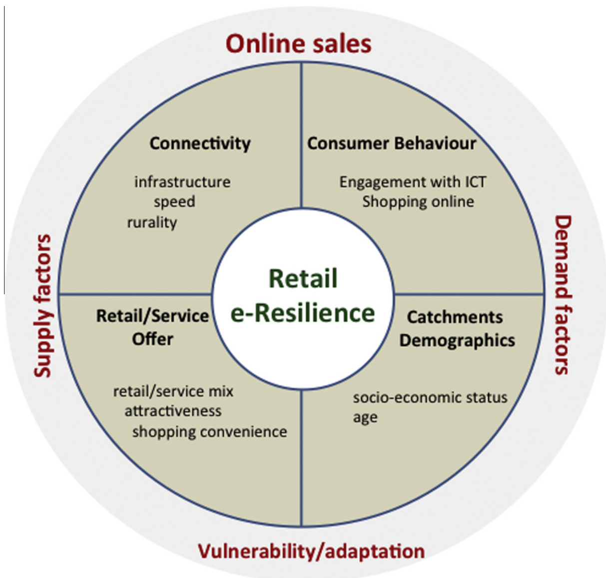

Fig. 1. A conceptual framework of e-resilience.

online substitution rates (Weltevreden, 2014). In other words, customers who have relatively easy access to the most attractive stores that are enhanced by adjacent leisure facilities tend to visit town centres for longer periods of time, and are normally expected to spend more within them (Hart and Laing, 2014; Wrigley and Lambiri, 2014). Furthermore, it has also been well documented that the impact of online shopping is not uniform across retail types (Zentner, 2008; Ryan and Been, 2013; Parker and Weber, 2013). Typically, retailers who merchandise goods that can be easily digitised such as music, videos, computer games or books are amongst the most vulnerable (Zentner et al., 2013). Use of the Internet for these retail types is estimated at 44% (ONS, 2014), which makes them susceptible to competition from online retailers.

Constructing a measure of e-resilience for a retail centre requires an array of knowledge about the characteristics and mix of retail offerings, alongside demographic and probable Internet engagement characteristics of likely consumers. An empirical model must therefore ensure that influences of both supply and demand can be estimated, and consideration is required about how these measures interact. Such issues are explored in the remaining sections of this paper, however, Fig. 1 summarises the range of influences on retail e-resilience as including: connectivity, behaviour, demographics and the retail/service offer.

3. Demand factors and Internet engagement behaviour

Demand and Internet engagement behaviours have been shown to map onto a range of influencing factors pertaining to the characteristics of people and the places in which they live (Longley and Singleton, 2009; Van Deursen and Van Dijk, 2011). Across a range of contexts, influences have been identified as including: demographics, such as age (Rice and Katz, 2003; Warf, 2013), socio-economic status (Silver, 2014), ethnicity (Wilson et al., 2003) or gender (Prieger and Hu, 2008); context, including rurality (usually measured by population density or road connectivity: Warren, 2007), education (Helsper and Eynon, 2010); and finally, Internet connectivity, including the underlying infrastructure that is available within an area to facilitate users getting online (Maillé and Tuffin, 2010; Grubesic and Murray, 2002), and the speed of connection that these access modes enable (Riddlesden and Singleton, 2014). A behavioural component captures the decision whether or not to use the Internet for a given activity, over any number of other modes of access. Influencing such decisions are both demographic effects, mainly age and socio economic status, and local retail supply including 'softer factors' such as convenience and accessibility.

Representing the multidimensional and interacting geography of such influences is complex, but has nevertheless previously been illustrated as tractable through geodemographic classification (Longley et al., 2008). The advantage of such methods vis-à-vis univariate measures or scaled composite indicators (e.g. such as a measure of "deprivation") are that geodemographics enable the summary of a wider range of influences on Internet user behaviours, and furthermore, enable greater opportunity for differentiation where influencing factors are not necessarily co-linear. For example, differentiating between areas of low engagement that are constrained by infrastructure, versus those constrained by demographics and attitudes.

Geodemographics ascribe categories that aim to summarise the salient characteristics of small areas through comparison of attributes related to resident populations, associated behaviours and features of the built environment (Harris et al., 2005). Such classifications have been applied in a variety of international settings over numerous substantive contexts (Singleton and Spielman, 2014); and is a technique commonly used in retail analysis for consumer segmentation (Birkin et al., 2002). Although general-purpose geodemographic classifications have demonstrated utility for exploration of Internet usage behaviours (Bunyan and Collins, 2013), as illustrated by Longley et al. (2008), there are sound reasons for developing purpose-specific classifications within this context. Logic follows that area differentiation is most effectively achieved through a geodemographic where the inputs are tailored to those outcomes that the classification is being designed to measure, providing enhanced performance and a stronger theoretical rationale for those attributes selected (Singleton and Longley, 2009).

As such, it is necessary to capture a composite of influences on demand, which are assembled within our e-resilience framework through creation of a purpose specific geodemographic, referred to going forward as the Internet User Classification (IUC). Guided by those past empirical studies that were highlighted in the literature presented earlier in this section, attributes of influence were organised into a typology of inputs comprising domains and more specific sub-domains. These are summarised in Table 1 and mapped onto input measures in the Appendix. These data were assembled at a 2011 Lower Layer Super Output Area (LSOA) scale for England, which comprises 32,844 zones of between 1,000 and 3,000 people, and 400 and 1,200 households. Most data were available for all of Great Britain, albeit that those datasets available for England were more robust, and so the decision was taken to exclude Scotland and Wales from the analysis.

An important source of data forming input to the IUC was the Oxford Internet Survey (OXIS), which was launched by the Oxford Internet Institute (OII)[1] in 2003, with subsequent surveys conducted biannually. Each survey implements a multi-stage national probability sample design for around 2000 people in Great Britain, enabling projection of estimates to Great Britain as a whole and comparison over time. Full details of the survey and methods can be found on the OXIS website,[2] and for this research we used responses from the latest 2013 study. A Small Area Estimation (SAE) technique was applied to each question and generated a predicted response rate at the LSOA level. This process was multi-staged, first implementing decision tree modelling for each OXIS survey

[1] http://oxis.oii.ox.ac.uk/.
[2] http://oxis.oii.ox.ac.uk/research/methodology/.

Table 1
Domains and subdomains of influence upon Internet behaviour.

Domain	Sub domain
Demographic	Age Density
Education	HE Qualifications
Employment	Occupation Access
Engagement	Attitude Business Civic Engagement Commerce Finance Finance Mobile Mobile Retail
Infrastructure	Connectivity Other Wireless/Mobile

Table 2
Structure and labels of the Internet User Classification (IUC).

Supergroup	Group
1: E-unengaged	1a: Too Old to Engage 1b: E-marginals: Not a Necessity 1c: E-marginals: Opt Out
2: E-professionals and students	2a: Next Generation users 2b: Totally Connected 2c: Students Online
3: Typical trends	3a: Uncommitted and Casual Users 3b: Young and Mobile
4: E-rural and fringe	4a: E-fringe 4b: Constrained by Infrastructure 4c: Low Density but High Connectivity

response, with covariates derived from non-response survey attributes and by geocoding the responder postcode. Predictor variables selected were based on those factors known to influence Internet use and behaviour that were identified earlier in this section, and include: age, social grade and population density quintile (as a proxy for rurality). A range of other attributes were evaluated, however these had limited influence, and as such were removed to improve model parsimony. The models output a series of rates which were then fitted to Output Areas zones (OA: minimum 40 households and 100 people) by examining the distribution of these population sub-groups within each OA nationally. In a sense, the OA rate for each question was a weighted average derived from all the population sub-groups present within it. We performed external validation of the OA estimates by profiling with a geodemographic (ONS Output Area Classification[3]) to ensure that the propensity for certain responses (e.g. the use of smartphones) were in line with responses given the general demographic profile of the clusters. Secondly, we also examined how our nation-wide and regional estimates differed from those derived through the original OXIS sample. In all instances our estimates were consistent with those from the OXIS sample, with no statistically significant differences in their distributions. Input into the classification required aggregation of the rates from OA to LSOA.

In addition to OXIS, attributes related to both fixed line and mobile Internet enabling infrastructures were assembled. Data comprising 4.7-million unit postcode level crowd sourced Internet speed test results were made available from broadbandspeedchecker.co.uk,[4] enabling average access speeds to be compiled for each LSOA. Detailed consideration of the spatio-temporal characteristics of these data can be found elsewhere in Riddlesden and Singleton (2014). Additionally, given that cellular signal strength becomes constrained as the distance from a cell tower increases (Godara, 2001), a proxy for access speed was created for each LSOA by calculating the population weighted centroid distance to the nearest phone mast using the Ofcom 'Sitefinder' database.[5] Finally, a range of socio-demographic indicators from the 2011 census was collated, including: levels of education, employment sector, prevalence of full-time students, age structure and population density. All variables considered as inputs to the classification were evaluated for their discrimination potential, and where possible, were limited to those without strong correlation; as such effects can overly influence the form of a final classification (Harris et al., 2005). Inputs were normalised using a Box–Cox transformation (Box and Cox, 1964), and were then range standardised onto the same measurement scale (Wallace and Denham, 1996). These are common types of transformation and standardisation implemented in the creation of geodemographic classifications (Vickers and Rees, 2007), and are deemed necessary to reduce the influence of skew, and additionally to ensure that all variables are ascribed equal weighing. After input measures are assembled, a geodemographic classification is created using a clustering algorithm, which is a class of computational method that aims to assign each record (in this case an LSOA) into a cluster based on similarity across the full range of input attributes.

This classification was created using the *K*-means clustering algorithm[6] with a "top-down" implementation; running the classification procedure for multiple iterations in order to attain an optimised result for each cluster frequency selected (Spielman and Singleton, 2015). This process first created an initial 'coarse' tier referred to as 'Supergroups' before re-clustering data within these assignments to form a second nested 'Group' level. Numerous different cluster frequencies were tested, with varying interpretability of the cluster characteristics and classification performance assessed. This evaluation included mapping and empirical testing of cluster fit through within sum of squares statistics. The final classification formed a nested hierarchy of 4 Supergroups and 11 Groups. Cluster mean values were then calculated for each of the input attributes and used to create 'Pen Portraits' (see Appendix) by considering variability in these scores between clusters. These textual descriptions provide an overview of the salient characteristics of each cluster, and are also summarised with Supergroup and Group names (see Table 2). An interactive map of the classification is available on the companion website: http://maps.cdrc.ac.uk/#/geodemographics/iuc14/, and can also be downloaded here: https://data.cdrc.ac.uk/dataset/cdrc-2014-iuc-geodata-pack-england.

4. Retail centre vulnerability and supply

Measuring the vulnerability of competing retail destinations to consumers of differential Internet engagement characteristics requires an understanding of the location and geographic extent of retail centres, combined with some assessment of their composition and size. A widely-accepted measure of retail area extent in the UK was developed through work funded by the Office of the Deputy Prime Minister in the late 1990 and early 2000s. This technique was later employed by the Department for Communities and

[3] http://www.opengeodemographics.com/.
[4] http://broadbandspeedchecker.co.uk.
[5] http://sitefinder.ofcom.org.uk/.

[6] *K*-means is stochastic and sensitive to those conditions used to initiate the algorithm; as such, and as is common practice in the creation of geodemographics, the algorithm was run 10,000 times, with an optimal run isolated through comparison of a within sum of squares statistic.

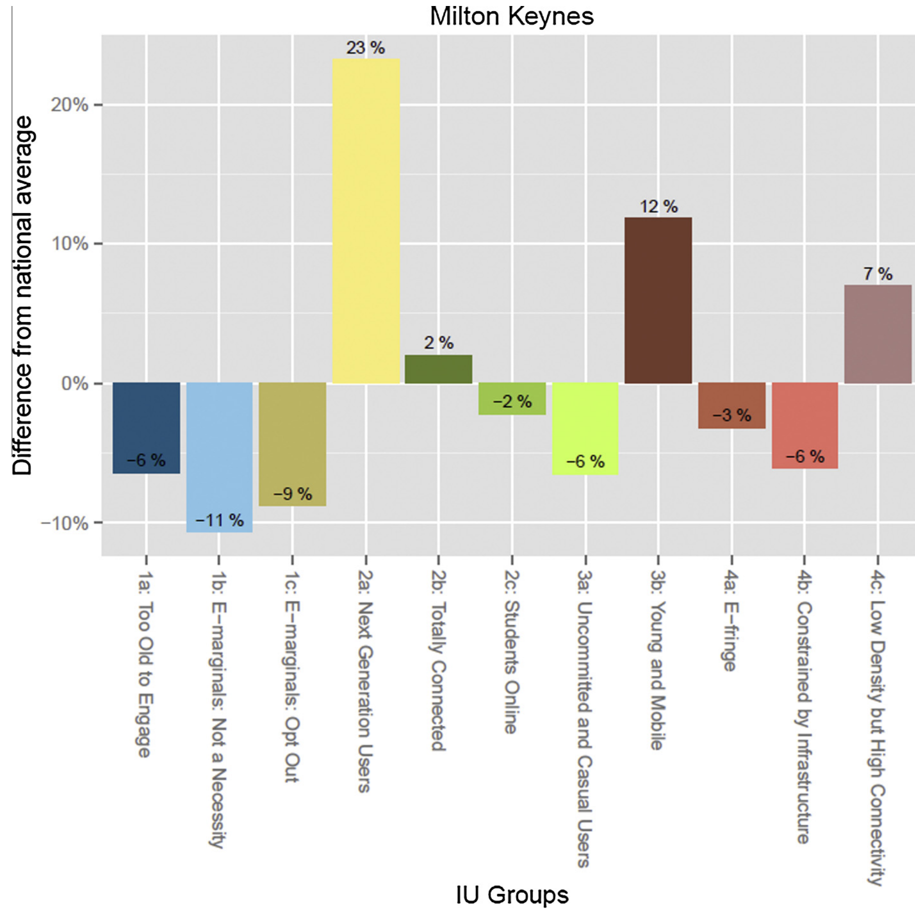

Fig. 2. IUC catchment profile for central Milton Keynes retail centre.

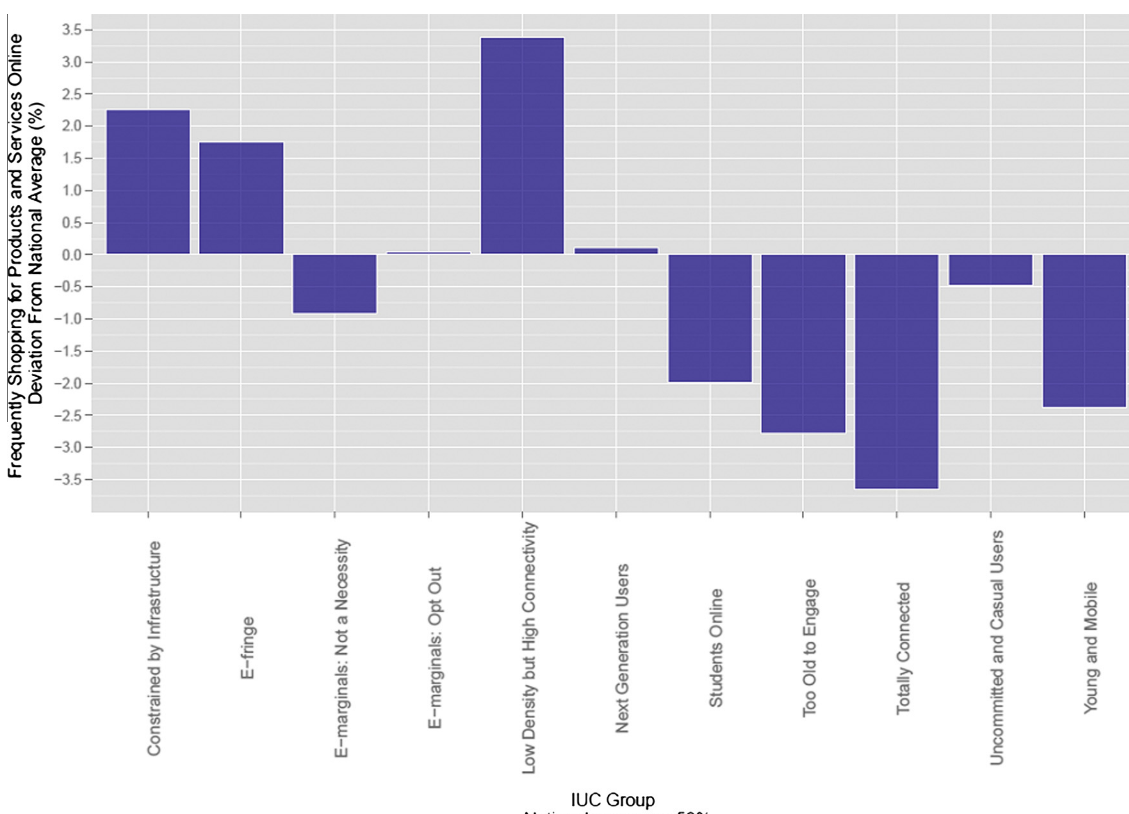

Fig. 3. Propensity to shop online by IUC Groups (OXIS Question – QC30b ‘Frequently buy products online’).

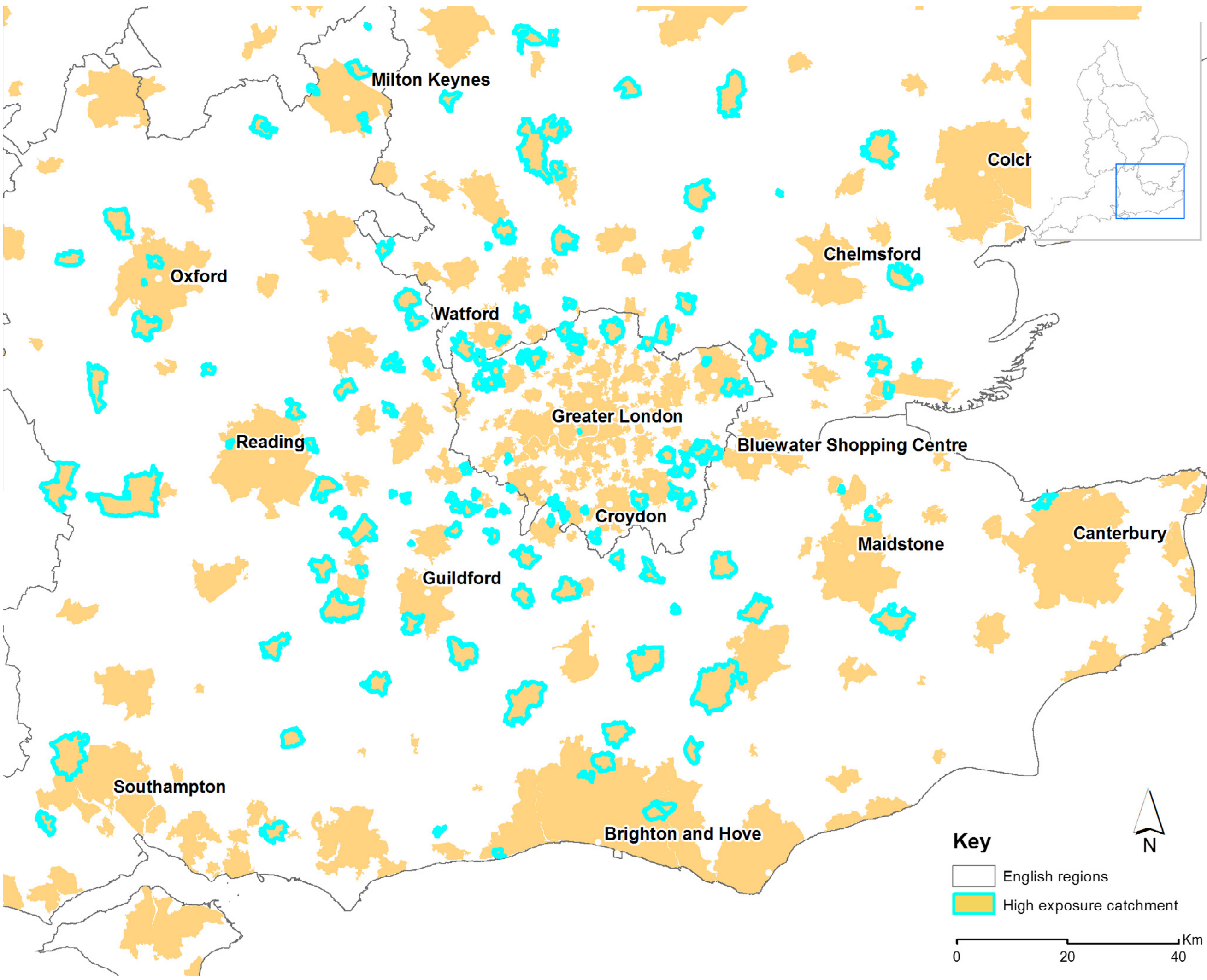

Fig. 4. Highly exposed retail centres in SE England.

Local Government (DCLG) to derive a set of retail centre zones that were used to form a database of information that featured in the State of the Cities Report (http://goo.gl/mtX1aB). These boundaries provide a systematic estimate of where the main concentrations of shops are found between different locations, although do not give information about the composition of competing retail opportunities. However, a nationally expansive record of the location, occupancy and facia of UK retail stores are generated by the Local Data Company (LDC: http://www.localdatacompany.com/), a commercial organisation that employs a large survey team to collect these data on a rolling basis. A national extract for February 2014 was made available for this research, with each record comprising the location of a retail premise with latitude and longitude coordinates, and details of the current occupier.

These data were used to calculate a series of measures which were informed by the literature to either enhance physical store attractiveness, or, to represent retail category vulnerability, where there would be risk of the main product offerings switching from physical to online channels. A composite of these measures forms a "supply vulnerability index" that is later integrated into the e-resilience score. Input measures to this index included the weighted percentage of anchor stores[7] (Feinberg et al., 2000; Damian et al., 2011) and leisure outlets (Reimers and Clulow, 2009); which are countered by the prevalence of 'digitalisation retail'. The latter measure captured the following categories: newsagents, booksellers, audio-visual rental, computer games, home entertainment, records, tapes & CDs and video libraries, as specified by the Oxford Institute of Retail Management (2013). As such, higher proportions of 'digitalisation retail' are associated with enhanced vulnerability of retail centres, whereas higher proportions of anchor store and leisure units indicated greater resilience.[8] A *supply vulnerability index* was then generated for each retail centre by creating a composite *z* score for each variable, and computing an average for each centre. The final score was scaled between 1 and 100.

5. Reconciling supply and demand

Estimating the exposure of retail centres to populations who are active Internet users as defined through the IUC required a method of modelling consumer flows to probable retail destinations. There is a long history and well developed literature on the ways in which such supply and demand for retail centres can be reconciled

[7] Anchor stores were defined as the 20 most attractive/largest stores as presented by Wrigley and Dolega (2011).

[8] Due to data availability, the percentage of stores within each retail centre rather than share of floor area was used. However such measure may be prone to a degree of bias as typically anchor stores are of larger size, therefore, this was addressed by increasing their weighting.

through catchment area estimation (Wood and Reynolds, 2012; Birkin et al., 2002, 2010). These techniques range in sophistication from calculating the geographic extent that people might be willing to travel to a retail centre in a given time (Grewal et al., 2012), through to more complex mathematical models that are calibrated on the basis of how attractive different retail offerings are to consumers living in different places (Newing et al., 2015). This latter group of models typically makes assumptions that larger towns with more compelling retail and leisure offerings are more attractive, but these effects decay with distance. Full details of the methodology and software to calibrate bespoke models lies outside the scope of this paper, and can be found in Dolega et al. (2016). However, in brief, catchments were estimated using a product constrained Huff model (Huff, 1964), with inputs including town centre composition and vacancy, and was implemented using distance decay functions calibrated using road network distance, and retail centre morphology proxied by ease of access and centre's position within retail hierarchy.

Once catchment areas had been estimated, we examined exposure through the intersection of the IUC groups presented earlier (Table 2). An example of a catchment profile for the Milton Keynes retail centre, which is within a city north of London, is shown in Fig. 2. This considers the proportion of the population within each of the IUC Groups, relative to the England average. In this example, it can be seen that the three of the eleven groups are over represented within this retail catchment, and similar profiles were calculated for all retail centres.

As discussed earlier, the IUC captures a range of influences on Internet user behaviour, however for the purposes of this analysis, those IUC groups with the highest and lowest propensity for online shopping were identified using the OXIS (see Fig. 3). Nationally, rates of online shopping equate to 53%, however there are differences between IUC Groups. For example, 4c (low density but high connectivity), 4b (constrained by infrastructure), 4a (e-fringe) and 2a (next generation users) are most likely to engage in online shopping; whereas: 3a (uncommitted and casual users), 1b (e-marginals: not a necessity) and 3b (young and mobile) have lower than average propensities. As such, the proportion of people within the overrepresented groups (4a, 4b and 4c) were calculated

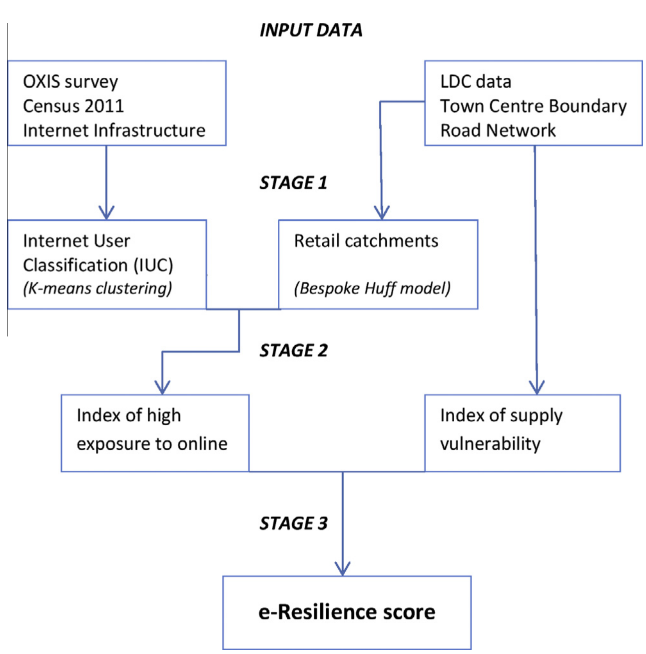

Fig. 5. Flow diagram showing how the e-resilience scores were calculated.

Table 2a
The 20 most e-resilient town centres.

Town centre	Region	e-resilience score
Boughton	East Midlands	100.00
Ravenside Retail Park, Bexhill-on-Sea	South East	97.58
Corbridge	North East	93.27
Torport	South West	71.61
Hersham	South East	70.29
Halton, Leeds	Yorkshire and the Humber	69.29
Cinderford	South West	68.51
Marsh Road, Luton	East of England	67.01
South Molton	South West	65.41
Parkgate Retail World	Yorkshire and the Humber	64.37
Carcroft	Yorkshire and the Humber	62.88
Chadderton	North West	60.74
Newburn	North East	60.45
Ventura Road Retail Park, Bitterscote	West Midlands	57.54
Feltham	Greater London	57.16
Teesside Park, Middlesbrough	North East	56.98
Kingston Park	North East	56.92
Sky Blue Way, Coventry	West Midlands	56.82
Crediton	South West	56.36
White Rose Centre	Yorkshire and the Humber	56.28

Table 2b
The 20 least e-resilient town centres.

Town centre	Region	e-resilience score
Rochford	East of England	1.00
London Road, Leigh-on-Sea	East of England	15.61
North Seaton Industrial Estate	North East	16.86
Whalley	North West	17.20
Oxted	South East	17.25
Barnt Green	West Midlands	17.39
Eccleshall	West Midlands	17.39
Hurstpierpoint	South East	17.98
Botley Road, Oxford	South East	18.14
Woburn Sands	South East	18.52
Potton	East of England	19.05
Shenfield Station	East of England	19.08
Bradford-on-Avon	South West	19.17
Great Dunmow	East of England	19.83
Longbenton	North East	20.37
Chalfont St. Peter	South East	20.75
Epworth	Yorkshire and the Humber	20.86
Sawbridgeworth	East of England	21.01
Ampthill	East of England	21.32
Old Bexley	Greater London	21.91

for each retail centre catchment, and again scaled into the range 1 and 100, forming an *index of high exposure*.

The index of high exposure indicates a rather remarkable spatial pattern. Fig. 4 maps those catchments with high exposure to online retail, defined here as possessing an index over the mean. The pattern emerging from this analysis is that predominantly secondary and tertiary retail centres (Dennis et al., 2002) located in more rural areas, including the satellite centres of more urbanised areas, reveal the greatest exposure to the impacts of online sales. This trend is reiterated for other parts of the country, although the majority of the highly exposed retail centres can be found within the South East. Moreover, based on those attractiveness scores that fed into the catchment model, it is worth noting that none of the

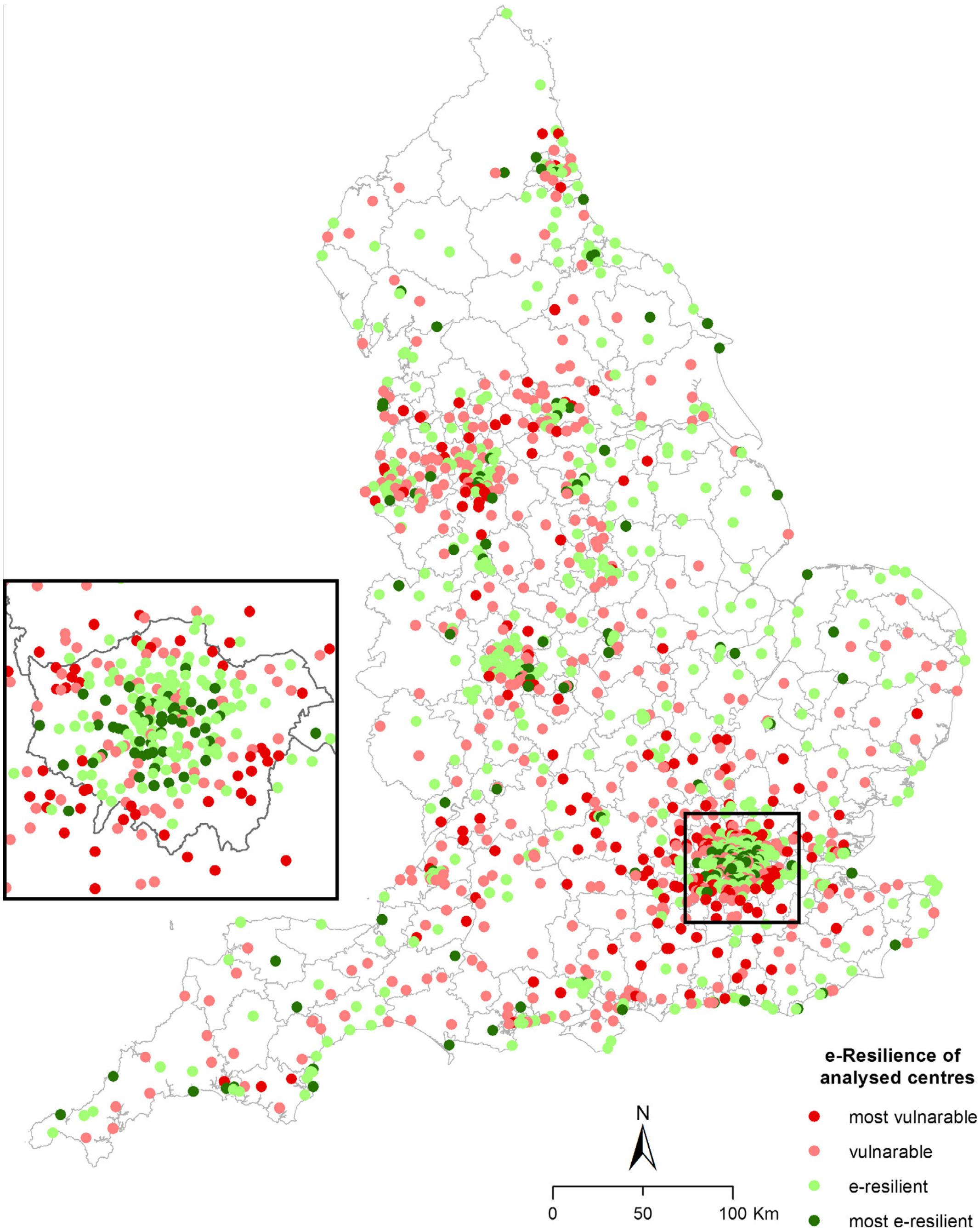

Fig. 6. The e-resilience of town centres in England.

highly exposed centres were drawn from the larger, most attractive centres, unlike the fortunes of many of the surrounding smaller towns and local shopping centres.

The index of high exposure and the supply vulnerability index were then combined to ascribe a measure of e-resilience to each individual retail centre. The indices were summed, and then the final score scaled into the range 1 and 100. The simple flow diagram in Fig. 5 shows the input datasets, different stages and outputs used to calculate the e-resilience scores.

Tables 2a and 2b show the 20 most and least e-resilient retail centres, with Fig. 6 mapping the e-resilience levels for the national extent, with scores divided into quartiles. The intersection of these two indicators reveals a remarkable spatial pattern. The most attractive retail centres, in particular the inner areas of the larger urban areas such as Greater London, Birmingham or Manchester demonstrated the highest levels of e-resilience, followed by the small local centres. Conversely, the least e-resilient centres were predominantly located in the suburban and rural areas of South East England, and to a lesser degree around other major conurbations of the country. Typically, these were the secondary and medium sized centres, often referred to as 'Clone Towns' (Ryan-Collins et al., 2010). It could be argued that this is largely intertwined with the geography of Internet shopping, where customers in more remote locations, typically faced with poorer retail provision, have displayed a higher propensity for online shopping. Nevertheless, these findings can also be associated with a polarisation effect, implying that large and attractive centres function as hubs for higher order comparison shopping and leisure; whereas the small local centres provide everyday convenience shopping, but the mid-sized centres have a less clear function. Combining such effects with higher exposure to online sales, retailers may be increasingly faced with too much physical space, and therefore may be inclined to downsize their store portfolio in such secondary locations first, as the space offered is often of a wrong size and configuration (BCSC, 2013).

6. Discussion and conclusions

The growth of Internet sales is increasingly viewed as one of the most important forces currently shaping the evolving structure of retail centres (Wrigley and Lambiri, 2014; Hart and Laing, 2014). Although current research does not suggest a death of physical space, the consequences for traditional high streets remain unclear as knowledge about the geography and drivers of Internet shopping are still limited. However, what is evident is that the pace of change in some retail centres has been more rapid than in others, and that multi-channel shopping has generated different requirements, not only in the terms of physical shopping space, but also in the expectations of an increasingly technology-driven consumer (BCSC, 2013; Kacen et al., 2013).

This study has introduced the concept of *e-resilience* as a framework through which the vulnerability of physical retail centres to the impact of online shopping behaviour can be assessed at a spatially disaggregate scale and for a national extent. Importantly, the measurement task required a trade-off between a number of challenges such as the degree of generalisation and the availability of data to inform model specification. For instance, the impact of online sales within a centre may range from damaging to some smaller retailers through to complementary in the case of various large multiples. In order to capture these complexities a number of assumptions were made such as the type of retail typically associated with the detrimental impacts and vice versa. Operationalising this measure of e-resilience required a novel methodology that conflated a range of data sources to develop two national indicators of retail centre exposure and vulnerability to online sales. These indices of supply and demand were then coupled through a retail centre catchment model.

The combined e-resilience measure revealed a geography where attractive and large retail centres such as the inner cores of large metropolitan areas were highlighted as more resilient, along with smaller more specialist centres, which perhaps served convenience shopping requirements. The centres identified as most vulnerable included many secondary and medium sized centres, which layers additional risk on top of those issues highlighted elsewhere such as a lack of diversity, or space not appropriately configured to a contemporary retail system (Ryan-Collins et al., 2010).

The findings of this study should be viewed as novel, and can be used to inform policy decisions. The three major implications of this project are as follows. First, it establishes the concept of e-resilience that examines retail centre exposure to the impact of Internet sales, and proposes a new methodology about how such interactions can be measured. Second, a comprehensive classification of retail centres based on their e-resilience levels provides a resource that can be used by a wide range of stakeholders including academics, retailers and town centre managers. For example, such outcomes could be used as assessment tools when evaluating retail centre economic performance. Third, the study adds value to and repositions the focus of current debates on the resilience of traditional high streets, which have predominantly concentrated on supply side measure such as vacancy rates.

Although there is no doubt that the concept of e-resilience, and the deliverable measures have both intuitive validity and practical application, this study is not free from limitations. The first relates to the availability of data that can be used to measure the e-resilience of retail centres. For instance, it may be difficult to capture comprehensively the vulnerability of retail centres using merely quantitative indicators; and in particular, those softer experiential factors may not be well reflected. The second is the extent to which supply and demand factors influence the e-resilience scores. The measure of e-resilience was calculated by simply adding the indexes of high exposure and supply vulnerability together. This presupposes that each index (that captures demand and supply respectively) is equally weighted and hence supply and demand has equal importance in terms of measuring e-resilience. These arbitrary equal weights for demand and supply might be validated against data on changing retail centre fortunes as these become available. A potential route to such validation may be sourced through the pooling of consumer data related to de facto online and offline consumption patterns. Finally, by examining e-resilience at a centre level, we have imposed a degree of generalisation in terms of composite retailer function, configuration and ownership. Further research is also required to explore how individual retailers respond to variable levels of exposure to consumers with differing Internet consumption characteristics. Such measures might be refined by sourcing retail floorspace estimates as a substitute for number of retail units and the arbitrary weighting of anchor stores. Opening hours and the range and availability of leisure facilities are also of clear importance in establishing the competitiveness of retail centres in comparison with online offers.

The concept of e-resilience contributes considerably to our current understanding of the nature and impact that Internet user behaviour is having on retail centres within the UK. International comparisons are clearly a fertile area for future research – for example some technologically advanced nations, such as South Korea, report lower levels of Internet sales than the U.K. As the penetration of online consumption is still steadily increasing, operational tools such as those offered by this study will have increasing policy relevance.

Acknowledgments

This research was funded by the Economic and Social Research Council, grant numbers ES/L011840/1; ES/L003546/1. We gratefully acknowledge the helpful and constructive comments of three anonymous reviewers.

Appendix A. IUC input measures

Measure	Sub domain	Domain	Source
Persons aged 0–4	Age	Demographic	Census
Persons aged 5–7	Age	Demographic	Census
Persons aged 8–9	Age	Demographic	Census
Persons aged 10–15	Age	Demographic	Census

(*continued on next page*)

Appendix A (*continued*)

Measure	Sub domain	Domain	Source
Persons aged 16–17	Age	Demographic	Census
Persons aged 18–19	Age	Demographic	Census
Persons aged 20–24	Age	Demographic	Census
Persons aged 25–29	Age	Demographic	Census
Persons aged 30–44	Age	Demographic	Census
Persons aged 45–59	Age	Demographic	Census
Persons aged 60–64	Age	Demographic	Census
Persons aged 65–74	Age	Demographic	Census
Persons aged 75–84	Age	Demographic	Census
Persons aged 85–89	Age	Demographic	Census
Persons aged 90 plus	Age	Demographic	Census
Population density persons per hectare	Density	Demographic	Census
Persons with no qualifications	Qualifications	Education	Census
Persons with level one qualifications	Qualifications	Education	Census
Persons with level two qualifications	Qualifications	Education	Census
Persons who are apprentices	Qualifications	Education	Census
Persons with level three qualifications	Qualifications	Education	Census
Persons with level four qualifications	Qualifications	Education	Census
Persons with other qualifications	Qualifications	Education	Census
Full time students	HE	Education	Census
Managers, directors and senior officials	Occupation	Employment	Census
Professional occupations	Occupation	Employment	Census
Associate professional and technical occupations	Occupation	Employment	Census
Administrative and secretarial occupations	Occupation	Employment	Census
Skilled trades occupations	Occupation	Employment	Census
Caring, leisure and other service occupations	Occupation	Employment	Census
Sales and customer service occupations	Occupation	Employment	Census
Process, plant and machine operatives	Occupation	Employment	Census
Elementary occupations	Occupation	Employment	Census
Seeking info holiday/journey – Internet	Commerce	Engagement	OXIS
Seeking info holiday/journey – Smartphone	Commerce	Engagement	OXIS
Frequently compare prices online	Commerce	Engagement	OXIS
Frequently order food or groceries online	Commerce	Engagement	OXIS
Frequently sell things online	Commerce	Engagement	OXIS
Seeking info topic/professional project – Internet	Business	Engagement	OXIS
Seeking info topic/professional project – Smartphone	Business	Engagement	OXIS
Have found a job through the Internet	Business	Engagement	OXIS
Frequently pay bills online	Finance	Engagement	OXIS
Frequently use online banking	Finance	Engagement	OXIS
Use mobile phone for email	Mobile	Engagement	OXIS
Use mobile for posting videos and photos online	Mobile	Engagement	OXIS
Use mobile phone for navigation	Mobile	Engagement	OXIS
Use mobile phone for social networking	Mobile	Engagement	OXIS
Use mobile phone for apps	Mobile	Engagement	OXIS
Use mobile phone for browsing the Internet	Mobile	Engagement	OXIS
Internet important for information	Attitude	Engagement	OXIS
Internet important for entertainment	Attitude	Engagement	OXIS
Interested in the Internet	Attitude	Engagement	OXIS
Use Internet while travelling – mobile/dongle	Mobile	Engagement	OXIS
Mostly use mobile phone for Internet	Mobile	Engagement	OXIS
Have saved money buying online	Finance	Engagement	OXIS
Frequently buy products online	Retail	Engagement	OXIS
Current Internet users	Access	Engagement	OXIS
Ex Internet users	Access	Engagement	OXIS
Internet non users	Access	Engagement	OXIS
Seeking info MP – Internet	Civic Engagement	Engagement	OXIS
Seeking info MP – Smartphone	Civic Engagement	Engagement	OXIS
Seeking info council tax – Internet	Civic Engagement	Engagement	OXIS
Seeking info council tax – Smartphone	Civic Engagement	Engagement	OXIS
Households that have Internet access at present	Connectivity	Infrastructure	OXIS
Households that don't have Internet access but have had in past	Connectivity	Infrastructure	OXIS

Appendix A (*continued*)

Measure	Sub domain	Domain	Source
Households that have never had Internet access	Connectivity	Infrastructure	OXIS
Households that have had Internet access for ten years or more	Connectivity	Infrastructure	OXIS
Households with wireless access in home through Wi-Fi	Wireless/Mobile	Infrastructure	OXIS
Households with a tablet computer	Wireless/Mobile	Infrastructure	OXIS
Households with e reader	Other	Infrastructure	OXIS
Households with games console	Other	Infrastructure	OXIS
Households with a smart TV	Other	Infrastructure	OXIS
Mobile phone ownership	Wireless/Mobile	Infrastructure	OXIS
Local download speed	Connectivity	Infrastructure	Broadbandspeedchecker
Distance to closest mobile base station	Connectivity	Infrastructure	Ofcom

Appendix B. IUC Group Pen Portraits

Group 1a: Too Old to Engage

The Too Old to Engage Group is characterised by large elderly populations who show little or no engagement with the Internet across all applications. The proportion of residents aged 75 plus is higher than any Group in the IUC. As a result, Internet enabled device ownership is lower than the Supergroup average, and the lowest of any Group in the IUC. Abstinence from Internet use is higher than the Supergroup average and far above the national average. Enclaves of this Group are found in coastal and lower density rural areas that serve as retirement destinations. Infrastructure provision and performance is typically slightly below the national average. The Too Old to Engage Group accounts for 4% of all Lower Super Output Areas nationally.

Group 1b: E-marginals: Not a Necessity

Members of the E-marginals: Not a Necessity Group typically have low engagement with Internet applications, lower than average qualifications and higher than average rates of employment in blue collar occupations that are not heavily reliant on digital skills. Of those that do access the Internet, many do so using a smartphone. Residents of this Group tend to be found within urban areas characterised by high levels of material deprivation, although infrastructure provision and performance are in line with the national average. The E-marginals: Not a Necessity Group accounts for 10.4% of all Lower Super Output Areas nationally.

Group 1c: E-marginals: Opt Out

The E-marginals: Opt Out Group are characterised by low levels of engagement with the Internet for applications such as seeking information and entertainment, preferring instead more traditional media such as newspapers and television, in part reflecting the elderly demographic of this Group. Typically residents of this Group are aged 60 plus, with significantly higher than average incidence of those aged 65–84. Geographically, this Group tends to be found in affluent rural and fringe areas that are more sparsely populated and where infrastructure provision and performance is below the national average. Access to the Internet through mobile devices is below the national average. Those who do choose to use the Internet tend to use it for price comparison and occasional online shopping. Levels of qualifications are generally above the national average, and those members who are not retired will typically be employed in senior managerial, professional or skilled trade occupations. Abstinence is significantly higher than the national average, but the lowest within the Supergroup. The E-marginals: Opt Out Group accounts for 10.4% of all Lower Super Output Areas nationally.

Group 2a: Next Generation Users

The Next Generation Users Group is characterised by high levels of engagement across all applications of the Internet. Members of this Group are heavy smartphone users and typically access the Internet on the move and for applications such as email, social networking and navigation. However, they favour fixed line connections for most other tasks such as general browsing and seeking information. Device ownership is higher than the national average, and members of this Group are likely to own several Internet enabled devices, such as tablet computers, e-readers and smart TVs. Levels of qualification are high within this Group, with higher than average rates of degree and higher degree level qualifications. The age structure is young to middle aged, with members of this Group most likely aged between 25 and 44, and in some cases with young children. Employment tends to be in managerial, professional and technical occupations. General interest in the Internet is above the national average. Members of this Group are found in affluent, higher density suburban and city fringe areas where infrastructure provision and performance is above the national average. Next Generation Users are the second most heavily engaged Group within the IUC, behind Group 2b: Totally Connected and account for 10.2% of all Lower Super Output Areas nationally.

Group 2b: Totally Connected

The Totally Connected Group is characterised by the highest levels of engagement within the IUC and score higher than the Supergroup and national averages for most measures of engagement. This Group displays a clear preference to use the Internet by default for almost all applications. Members of this Group access the Internet through multiple devices, whilst on the move and in the home to ensure seamless connectivity. As such, device ownership is significantly higher than the national and Supergroup averages and members of this Group own a wide range of Internet enabled hardware. Levels of qualification are significantly higher than the national average. Professional occupations are most prevalent, with the age structure of residents being young to middle aged, sometimes with young children. Geographically, this Group tends to be found in affluent city centre and city fringe areas that are densely populated and where infrastructure provision and performance is above the national average. Members of this Group show below average rates of online shopping, perhaps given good local retail choice. However, rates of online shopping for food and groceries are significantly above the national and Supergroup averages as this enables wider choice and convenience in highly populated areas. Totally Connected are the most heavily engaged Group within the IUC and account for 4.8% of all Lower Super Output Areas nationally.

Group 2c: Students Online

Students Online represents a small but very distinct Group that is comprised almost entirely of student areas. The Group is characterised by very high levels of Internet usage, particularly through mobile devices. Smartphones are the device of choice for electronic communication and are used for a wide range of applications including email, social networking, third party applications, web browsing and sharing photos and videos. Members of this Group are typically aged between 18 and 24 and are registered as full time students. Interest in the Internet for information and entertainment is above the national average, and a higher than average proportion of the local population is likely to have found, or to be seeking, employment through the Internet. Employment across all sectors is below the national average with the exception of sales and customer service roles, in which some students choose to work, most likely on a part-time basis to support their studies. Geographically, this Group is often found in the major urban conurbations, usually within city centres and university campus areas where there are highly concentrated student populations. Infrastructure provision and connection performance is above the national average in these areas. The Students Online Group accounts for 1.7% of all Lower Super Output Areas nationally.

Group 3a: Uncommitted and Casual Users

The Uncommitted and Casual Users Group are characterised by mixed levels of engagement with the Internet. Access to the Internet through smartphones is marginally above the national average and access through fixed-line connections falls marginally below. Members of this Group show below average rates for purchasing online but above average rates for price comparison and selling online. Age structure is generally young to middle aged, with higher than average proportions of young and teenage children. Qualifications tend to be of a lower level and members of this Group are most likely to work in service, sales and elementary occupations. Overall, abstinence from Internet use is marginally higher than the national average and general interest in the Internet falls below the national average. This Group also contains higher than average numbers of lapsed Internet users. Geographically, this Group tends to be found in major urban and city fringe areas that suffer higher levels of material deprivation, but where infrastructure provision and performance is above the national average. The Uncommitted and Casual Users Group accounts for 15.5% of all Lower Super Output Areas nationally.

Group 3b: Young and Mobile

The Young and Mobile Group is predominantly young and has a tendency to access the Internet using mobile devices rather than fixed line connections. This Group is found in major urban conurbations where population density is above average and infrastructure provision is sufficient to support heavy mobile broadband usage. These areas are typically inner city or city fringe and experience mixed levels of material deprivation. As a Group there are higher than average proportions of young and teenage children and adults aged 25–44. Conversely, the proportion of adults aged over 45 falls below the national and Supergroup averages. All levels of qualification are below the national average and those who work are likely to be employed in elementary, sales or service occupations. Interest in the Internet for entertainment and information is above the national average, most likely reflecting the prevailing age structure. This Group displays a lower than average tendency to purchase online, and would be expected to shop locally in most cases. The Young and Mobile Group accounts for 11.5% of all Lower Super Output Areas nationally.

Group 4a: E-fringe

The E-fringe Group is distinguished by its location around the fringes of urban areas that are typically low density or semi-rural. Age structure is middle aged to elderly and there are fewer than average numbers of young adults aged 18–29, a group who are likely to have moved to more major urban conurbations. General interest in the Internet within this Group is slightly below the national average and the lowest within the Supergroup, rates of current Internet users are also below average and numbers of Internet non-users are above the national average. Members of this Group generally have mixed levels of qualifications and are most likely to work in administrative and secretarial or skilled trade occupations. The most common uses of the Internet within this Group are paying bills and banking online, comparing prices and buying products, which score above the national average. Below average rates are recorded for seeking information and entertainment purposes, consistent with the age profile of this Group. Equally, ownership of Internet enabled devices is below average, with the exception of e-readers, which are popular amongst this Group. Infrastructure provision and performance is marginally below the national average but would be unlikely to limit access. The E-fringe Group accounts for 11.1% of all Lower Super Output Areas nationally.

Group 4b: Constrained by Infrastructure

The Constrained by Infrastructure Group is characterised by locations in low-density rural areas where there is poor provision and performance of local Internet infrastructure, both fixed line and mobile. This limits engagement with some online applications. Fixed line broadband performance falls significantly below the national average and is the lowest within the Supergroup as 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, and as such further constrains performance and usability. Perhaps as a result, the use of mobile broadband through devices such as smartphones or dongles is below average. Despite poor infrastructure, general interest in the Internet is in line with the national average and members of this Group display above average rates of purchasing online, comparing prices, online banking and paying bills, most likely as this saves travelling to a local retail centre to access these services. Internet enabled device ownership is again lower than the national average with the exception of e-readers, likely due to the prevailing age structure of this Group, which is middle aged and elderly. Those who are not retired are generally highly qualified and work in managerial, professional or technical occupations. Internet non-use is above average but reflects the prevailing age profile of the Group. The Constrained by Infrastructure Group accounts for 11% of all Lower Super Output Areas nationally.

Group 4c: Low Density but High Connectivity

The Low Density but High Connectivity Group is found in areas that are sparsely populated, typically rural and semi-rural areas, or areas with urban parkland. Despite disparate populations, this Group is generally well connected and displays the strongest infrastructure and performance characteristics within the Supergroup, generally falling in line with the national average. Internet use is higher across all applications than the Supergroup average, and this Group shows a higher than average propensity for ordering food and groceries online. These characteristics are representative of the prevailing demographic of well-educated workers (often with degrees or higher degrees) who work in high-grade professional occupations. Similarly, Internet enabled device ownership is above the national average, perhaps because local infrastructure is able to support this. Age structure is mixed, although members of this Group are most likely to be aged 45–59 with young or teenage children. General interest in the Internet is above the national average and is the highest within the Supergroup. As would be expected, rates of Internet non-use are below the national average. The Low Density but High Connectivity Group accounts for 9.4% of all Lower Super Output Areas nationally.

References

BCSC, 2013. Beyond Retail: Redefining the Shape and Purpose of Town Centres. BCSC, London. <http://policy.bcsc.org.uk/beyondretail/docs/BeyondRetail2013.pdf> (accessed 05.08.15).

Birkin, M., Clarke, G., Clarke, M., 2002. Retail Geography and Intelligent Network Planning. Wiley, Chichester, NY.

Birkin, M., Clarke, G., Clarke, M., 2010. Refining and operationalizing entropy-maximizing models for business applications. Geogr. Anal. 42 (4), 422–445.

Box, G.E.P., Cox, D.R., 1964. An analysis of transformations. J. R. Stat. Soc.: Ser. B (Methodol.) 26 (2), 211–252.

Bunyan, S., Collins, A., 2013. Digital exclusion despite digital accessibility: empirical evidence from an English city: digital exclusion despite digital accessibility. Tijdschr. Econ. Soc. Geogr. 104 (5), 588–603.

Capgemini, 2015. Mobile Accounts for 40% of All Online Retail Sales. <https://www.uk.capgemini.com/news/uk-news/mobile-accounts-for-40-of-all-online-retail-sales> (accessed 05.08.15).

Centre for Retail Research, 2015. Online Retailing: Britain and Europe 2014. <http://www.retailresearch.org/onlineretailing.php> (accessed 21.03.15).

Christopherson, S., Michie, J., Tyler, P., 2010. Regional resilience: theoretical and empirical perspectives. Cambridge J. Reg. Econ. Soc. 3 (1), 3–10.

Dennis, C., Marsland, D., Cockett, T., 2002. Central place practice: shopping centre attractiveness measures hinterland boundaries and the UK retail hierarchy. J. Retail. Consum. Serv. 9 (4), 185–199.

Damian, D.S., Curto, J.D., Pinto, J.C., 2011. The impact of anchor stores on the performance of shopping centres: the case of Sonae Sierra. Int. J. Retail Distrib. Manage. 39 (6), 456–475.

Dawley, S., Pike, A., Tomaney, J., 2010. Towards the resilient region? Local Econ. 25, 650–667.

DCLG, 2013. The Future of High Streets. Progress since the Portas Review. <https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/211536/Future_of_High_Street_-_Progress_Since_the_Portas_Review_-revised.pdf> (accessed 28.10.15).

Digital High Street Advisory Board, 2015. Digital High Street 2020. <http://thegreatbritishhighstreet.co.uk/digital-high-street-report-2020> (accessed 21.03.15).

Doherty, N.F., Ellis-Chadwick, F., 2010. Internet retailing: the past the present and the future. Int. J. Retail Distrib. Manage. 38 (11/12), 943–965.

Dolega, L., Celinska-Janowicz, D., 2015. Retail resilience: a theoretical framework for understanding town centre dynamics. Stud. Region. Lokalne – Polish Sect. Reg. Stud. Assoc. 2 (60), 8–31.

Dolega, L., Pavlis, M., Singleton, A., 2016. Estimating attractiveness, hierarchy and catchment area extents for a national set of retail centre agglomerations. J. Retail. Consum. Serv. 28, 78–90.

Forman, C., Ghose, A., Goldfarb, A., 2008. Competition between local and electronic markets: how the benefit of buying online depends on where you live. Manage. Sci. 55 (1), 47–57.

Feinberg, R., Stanton, J., Keen, C., Kim, I.-S., Hokama, L., de Ruyter, K., 2000. Attraction as a determinant of mall choice. In: Proceedings of the 7th International Conference on Retailing and Services Science, European Institute of Retailing and Services Science, Eindhoven.

Grewal, D., Kopalle, P., Marmorstein, H., Roggeveen, A.L., 2012. Does travel time to stores matter? The role of merchandise availability. J. Retail. 88 (3), 437–444.

Grubesic, T.H., Murray, A.T., 2002. Constructing the divide: spatial disparities in broadband access. Pap. Reg. Sci. 81 (2), 197–221.

Godara, L.C., 2001. Handbook of Antennas in Wireless Communications. CRC Press, Boca Raton, FL.

Harris, R., Sleight, P., Webber, R., 2005. Geodemographics GIS and Neighbourhood Targeting. Wiley, Chichester, UK.

Hart, C., Laing, A., 2014. The consumer journey through the high street in the digital area. In: Wrigley, N., Brookes, E. (Eds.), Evolving High Streets: Resilience and Reinvention – Perspectives from Social Science. University of Southampton, Southampton, UK, pp. 36–39, <http://thegreatbritishhighstreet.co.uk/pdf/GBHS-HighStreetReport.pdf> (accessed 05.08.15).

Hassink, R., 2010. Regional resilience: a promising concept to explain differences in regional economic adaptability? Cambridge J. Reg. Econ. Soc. 3 (1), 45–58.

Helsper, E.J., Eynon, R., 2010. Digital natives: where is the evidence? Brit. Educ. Res. J. 36 (3), 503–520.

Huff, D.L., 1964. Defining and estimating a trade area. J. Market. 28 (3), 34–38.

Kacen, J.J., Hess, J.D., Kevin Chiang, W.-Y., 2013. Bricks or clicks? Consumer attitudes toward traditional stores and online stores. Glob. Econ. Manage. Rev. 18 (1), 12–21.

Longley, P.A., Singleton, A.D., 2009. Classification through consultation: public views of the geography of the E-society. Int. J. Geogr. Inform. Sci. 23 (6), 737–763.

Longley, P.A., Webber, R.J., Chao, L., 2008. The UK geography of the e-society: a national classification. Environ. Plan. A 40 (2), 362–382.

Maillé, P., Tuffin, B., 2010. Price war in heterogeneous wireless networks. Comput. Netw. 54 (13), 2281–2292.

Martin, R.L., 2011. Regional economic resilience hysteresis and recessionary shocks. J. Econ. Geogr. 12 (1), 1–32.

Martin, R.L., Sunley, P.J., 2007. Complexity thinking and evolutionary economic geography. J. Econ. Geogr. 7 (5), 573–602.

Newing, A., Clarke, G.P., Clarke, M., 2015. Developing and applying a disaggregated retail location model with extended retail demand estimations. Geogr. Anal. 47 (3), 219–239.

ONS, 2014. Internet Access – Households and Individuals 2014. Office for National Statistics, London. <http://www.ons.gov.uk/ons/rel/rdit2/internet-access—households-and-individuals/2014/stb-ia-2014.html> (accessed 05.08.15).

Oxford Institute of Retail Management, 2013. Diversity and the UK's High Streets. <http://oxford-institute.sbsblogs.co.uk/2013/07/19/diversity-and-the-uks-high-streets/> (accessed 06.08.15).

Parker, B., Weber, R., 2013. Second-hand spaces: restructuring retail geographies in an era of E-commerce. Urban Geogr. 34 (8), 1096–1118.

Pendall, R., Foster, K.A., Cowell, M., 2010. Resilience and regions: building understanding of the metaphor. Cambridge J. Reg. Econ. Soc. 3 (1), 71–84.

Portas, M., 2011. The Portas Review. An Independent Review into the Future of Our High Streets. <https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/6292/2081646.pdf> (accessed 15.06.15).

Prieger, J.E., Hu, W.-M., 2008. The broadband digital divide and the nexus of race competition and quality. Inf. Econ. Policy 20 (2), 150–167.

Raco, M., Street, E., 2012. Resilience planning economic change and the politics of post-recession development in London and Hong Kong. Urban Stud. 49 (5), 1065–1087.

Reimers, V., Clulow, V., 2009. Retail centres: it's time to make them convenient. Int. J. Retail Distrib. Manage. 37 (7), 541–562.

Rice, R.E., Katz, J.E., 2003. Comparing Internet and mobile phone usage: digital divides of usage adoption and dropouts. Telecommun. Policy 27 (8–9), 597–623.

Riddlesden, D., Singleton, A.D., 2014. Broadband speed equity: a new digital divide? Appl. Geogr. 52, 25–33.

Ryan, S., Been, C., 2013. Bricks-and-mortar: bookselling and supermarket philosophy. Int. J. Book 10 (2), 55–66.

Ryan-Collins, J., Cox, E., Potts, R., Squires, P., 2010. Re-imagining the High Street Escape from Clone Town Britain. New Economics Foundation, London.

Shobeiri, S., Mazaheri, E., Laroche, M., 2015. Shopping online for goods vs services: where do experiential features help more? Int. J. Consum. Stud. 39 (2), 172–179.

Silver, M.P., 2014. Socio-economic status over the lifecourse and Internet use in older adulthood. Age. Soc. 34, 1019–1034.

Simmie, J., Martin, R.L., 2010. The economic resilience of regions: towards an evolutionary approach. Cambridge J. Reg. Econ. Soc. 3 (1), 27–43.

Singleton, A.D., Longley, P.A., 2009. Creating open source geodemographics – refining a national classification of census output areas for applications in higher education. Pap. Reg. Sci. 88 (3), 643–666.

Singleton, A.D., Spielman, S.E., 2014. The past present and future of geodemographic research in the United States and United Kingdom. Prof. Geogr. 66 (4), 558–567.

Spielman, S.E., Singleton, A.D., 2015. Studying neighborhoods using uncertain data from the American community survey: a contextual approach. Ann. Assoc. Am. Geogr. 105 (5), 1003–1025.

Turner, J.J., Gardner, T., 2014. Critical reflections on the decline of the UK high street: exploratory conceptual research into the role of the service encounter. In: Musso, F., Drucia, E. (Eds.), Handbook of Research on Retailer–Consumer Relationship Development. IGI Global, Hershey, PA, pp. 127–151.

van Deursen, A., van Dijk, J., 2011. Internet skills and the digital divide. New Media Soc. 13 (6), 893–911.

Vickers, D., Rees, P., 2007. Creating the UK national statistics 2001 output area classification. J. R. Stat. Soc. Ser. A: Stat. Soc. 170 (2), 379–403.

Wallace, M., Denham, C., 1996. The ONS Classification of Local and Health Authorities of Great Britain. Studies on Medical and Population Subjects ONS Number 59.

Warf, B., 2013. Contemporary digital divides in the United States. Tijdschr. Econ. Soc. Geogr. 104 (1), 1–17.

Warren, M., 2007. The digital vicious cycle: links between social disadvantage and digital exclusion in rural areas. Telecommun. Policy 31 (6–7), 374–388.

Weltevreden, J., 2007. Substitution or complementarity? How the Internet changes city centre shopping. J. Retail. Consum. Serv. 14 (3), 192–207.

Weltevreden, J., 2014. The digital challenge for the high street: insights from Europe. In: Wrigley, N., Brookes, E. (Eds.), Evolving High Streets: Resilience and

Reinvention – Perspectives from Social Science. University of Southampton, pp. 32–35.
Williams, D.E., 2009. The evolution of E-tailing. Int. Rev. Retail Distrib. Consum. Res. 19 (3), 219–249.
Wilson, K.R., Wallin, J.S., Reiser, C., 2003. Social stratification and the digital divide social science. Comput. Rev. 21 (2), 133–143.
Wood, S., Reynolds, J., 2012. Leveraging locational insights within retail store development? Assessing the use of location planners' knowledge in retail marketing. Geoforum 43 (6), 1076–1087.
Wrigley, N., Dolega, L., 2011. Resilience, fragility and adaptation: new evidence on the performance of UK high streets during global economic crisis and its policy implications. Environ. Plan. A 43 (10), 2337–2363.
Wrigley, N., Lambiri, D., 2014. High Street Performance and Evolution: A Brief Guide to the Evidence. University of Southampton, Southampton, <http://thegreatbritishhighstreet.co.uk/pdf/GBHS-HighStreetReport.pdf> (accessed 05.08.15).
Wrigley, N., Lambiri, D., 2015. British High Streets: from Crisis to Recovery? A comprehensive review of the evidence. RIBEN. Available from: <http://www.riben.org.uk/Cluster_publications_%26_media/BRITISH%20HIGH%20STREETS_MARCH2015.pdf>.
Zentner, A., 2008. Online sales, Internet use, file sharing and the decline of retail music specialty stores. Inf. Econ. Policy 20 (3), 288–300.
Zentner, A., Smith, M., Kaya, C., 2013. How video rental patterns change as consumers move online. Manage. Sci. 59 (11), 2622–2634.