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de Vos, Duco; Meijers, Evert

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INFORMATION TECHNOLOGY AND LOCAL PRODUCT VARIETY: SUBSTITUTION, COMPLEMENTARITY AND SPILLOVERS

DUCO DE VOS & EVERT MEIJERS

Faculty of Architecture and the Built Environment, Delft University of Technology, Julianalaan 134, 2628BL Delft, the Netherlands. E-mail: d.w.devos@tudelft.nl (Corresponding author)

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ABSTRACT

This paper addresses the interaction between information technology (IT) and agglomeration. The literature distinguishes two types of interactions, namely a substitution effect and a complementarity effect. We conceptualise a third effect, namely a 'spillover' mechanism, by which IT allows places in close proximity of large cities to 'borrow size' and sustain greater product variety. We test these mechanisms using detailed data on restaurant cuisine variety in the Netherlands, and the IT dimension is measured through the use and penetration of online restaurant reviews. We find that IT complements cuisine variety in cities, and induces spillovers to smaller places near larger ones, allowing smaller places to sustain 'rare' cuisines that were traditionally only present in larger cities. As such, IT leads to the spread of agglomeration benefits such as local product variety over larger territories.

Key words: Information technology, agglomeration economies of consumption, spatial information frictions, product variety, restaurants

INTRODUCTION

Many industries exhibit a positive relationship between market size and product variety. A wide variety of local products is therefore seen as a typical urban benefit (Glaeser *et al.* 2001; Rosenthal & Strange 2004). The way in which information technology (IT) interacts with this local market size externality is part of a larger, polarised debate on the interaction between agglomeration economies and IT, that, is in need of new empirical substantiation now that (mobile) access to digital information and communication channels has reached unprecedented levels in recent years.

The literature that studies the interplay between IT and offline local variety offers mixed results. On the one hand, it is shown that internet technologies are more intensively used in rural areas, where offline alternatives of many services are not at hand (Sinai & Waldfogel 2004). On the other hand, it is often argued that the internet is more useful and beneficial in urban environments, where it can provide information on the bewildering amount of opportunities nearby, spurring demand that leads to the entry of new varieties of local products (Anenberg & Kung 2015).

Geographically, the essence of IT is that it eliminates spatial information frictions (Jensen 2007): access to most forms of information is almost ubiquitous. Decreasing spatial information frictions may not only complement the benefits of agglomeration in cities themselves, but may also allow these benefits to spill over to adjacent areas. By disseminating information about specific destinations, online information may decrease the uncertainty associated with travelling to these destinations, and thereby affect the generalised costs of travel (Mokhtarian & Tal 2013). If such an effect were sufficiently high, we would expect that places adjacent to large cities are increasingly able to capitalise on the population of their neighbours, for instance by drawing on their critical mass to sustain more specialised urban functions for which they themselves do not provide sufficient mass. Alonso (1973) coined the term 'borrowed size' for such spillover processes that weaken the strong relation between size and function of places as for instance predicted by central place theory (Christaller 1966). Within the debate on the substitution or complementary effect of IT on cities, the option of 'borrowed size' has not been considered.

We investigate the interaction between IT and local product variety using the restaurant industry in the Netherlands as a case study. This market is known for its strong relationship between market size and horizontal product differentiation (Berry & Waldfogel 2010), and the presence of a large variety of restaurant cuisines is understood as an urban consumption benefit (Glaeser *et al.* 2001; Couture 2013; Schiff 2015).[1] The restaurant market is also heavily affected by internet technologies. With the rise of IT, a large part of marketing activities of restaurants has moved online. Moreover, this market enjoys extensive online word-of-mouth, through major review websites such as Yelp, TripAdvisor, and national level counterparts, such as Iens.nl in the Netherlands (the geographical focus of our research). Research has shown that online reviews substantially affect purchase behaviour in markets for 'experience goods' in general (Huang *et al.* 2009), and in restaurant markets in particular (Anderson & Magruder 2011). Data from Google Trends shows that since 2004 there has been a dramatic increase in the use of restaurant review databases in the Netherlands, most notably the culinary website Iens.nl, and the general tourism review website TripAdvisor (see Figure 1).[2]

The research question guiding this paper is as follows: to what extent does IT interact with agglomeration economies of consumption? Thereby, we distinguish and explore the presence of three main mechanisms:

1. A substitution effect; this occurs when IT is of greater benefit in smaller places, for example, because online information has a higher value when offline substitutes such as physical comparison shopping and word-of-mouth are less available.
2. A complementary effect; this occurs when IT is of greater benefit in larger places, for example, because online information on local goods is more valuable in dense, congested areas.
3. A spillover effect; this occurs when IT allows smaller places in the vicinity of larger places to 'borrow size', and sustain more agglomeration benefits locally.

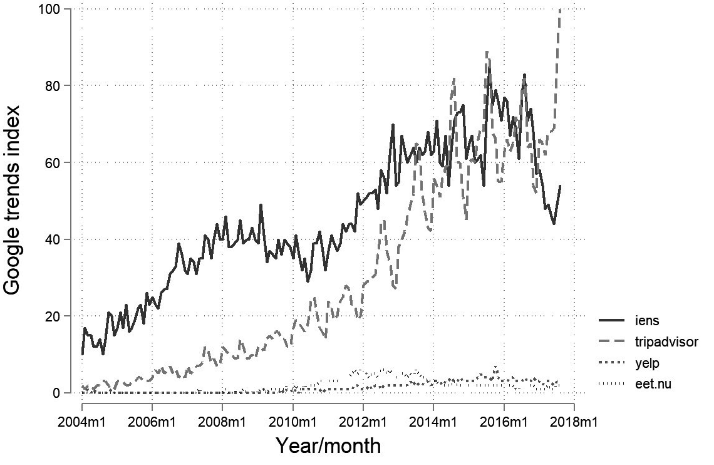

Figure 1. *Google trends results for online review databases in the Netherlands.*

By answering our research question we contribute to at least three strands of literature. First, we add to the literature that deals with the question whether IT substitutes or complements the consumption benefits of cities by examining the effect of a *direct* measure of online information on cuisine variety (Gaspar & Glaeser 1998; Sinai & Waldfogel 2004; Anenberg & Kung 2015). Second, we add to the literature that investigates the alternative sources of agglomeration externalities through borrowed size (Phelps *et al.* 2001; Meijers 2007; Meijers & Burger 2017) by highlighting potential ways in which the extent of markets may increase and enable positive agglomeration spillovers between places. Finally, we test whether the earlier established relationship between cuisine variety and local population in American metropolitan areas (Waldfogel 2008; Couture 2013; Schiff 2015) also holds in the Netherlands, and whether it is also present in a non-metropolitan context. Where earlier research was mainly focused on metropolitan areas, our analysis includes all places in the Netherlands with at least one restaurant.

The remainder of this paper is structured as follows. The next section further elaborates on the mechanisms by which online reviews interact with agglomeration and product variety. In the third section we discuss the data. In the fourth section we present our empirical approach. In the fifth section we present the results, and we subject our results to several sensitivity checks. The final section concludes.

AGGLOMERATION, ONLINE REVIEWS, AND CUISINE VARIETY

During the 1990s and early 2000s several authors declared that the 'death of distance' was near (Cairncross 1997), the world was increasingly becoming 'flat' (Friedman 2005), and that geography and proximity seemed to matter less and less, as a result of advances in IT and continuing globalisation. The economic and geographic literature concerned with this question continued to emphasise the ways in which distance still seems to matter (Goldfarb & Tucker 2017). It is, for instance, generally argued that tele or online communication complements face-to-face encounters, and that the increasing need for encounters offsets the decentralising effects of IT (Gaspar & Glaeser 1998; Leamer & Storper 2001). Next to that, it is argued that while the usage of IT is usually higher when real-world offline options are less available, for instance in rural areas, the welfare benefits of IT are greater in urban areas where information on local offline options is more valuable because it spurs demand for local goods, and allows the entry of new varieties (Sinai & Waldfogel 2004; Anenberg & Kung 2015).

The rise of online reviewing of restaurants is a prime example of how information technology has made information on local consumption options accessible. We believe there are three mechanisms by which these online reviews interact with agglomeration economies of consumption in the restaurant market.

First, online reviews may provide a substitute for word-of-mouth advertising and comparison shopping, traditionally fostered by physical proximity. Word-of-mouth advertising is local by definition. It requires face-to-face contact, and it can only involve restaurants that have been visited in person, which is more likely for restaurants close by. The effect of word-of-mouth may be declining, in favour of online reviews. Similarly, online reviews substitute physical comparison shopping: one of the traditional reasons for restaurants to cluster together in cities. By allowing potential customers a detailed comparison of restaurants before arriving at the scene, online presence in general, and online reviews in particular may substitute the need for restaurants to locate near one another. Thus the attractiveness of places where restaurants cluster – typically cities – would decrease in favour of places with a lower restaurant density. Following this mechanism the advent of online restaurant reviewing would substitute agglomeration economies of consumption.

Second, online reviews may be of greater value and effect in cities. It is argued that one of the main effects of IT is the reduction of spatial information frictions (Jensen 2007). Information about local goods has traditionally depended critically on proximity. By loosening the relationship between proximity and information, online information in general, and online reviews in particular may lead to increased demand for local goods, and thereby spur product variety. If, as Anenberg and Kung (2015) argue, spatial information frictions are more abundant in dense, congested cities with a bewildering amount of offline opportunities, then the variety economies of cities may be complemented by IT. Anenberg and Kung (2015) find such evidence for the food truck industry in metropolitan areas in the US.

Third, online reviews may influence the willingness to travel for restaurants, not only within, but also between places. In the transportation literature it is well established that ICT does not only substitute making trips, but also complements travel in many ways. Particularly, IT has a role in 'disseminating information about specific destinations' (Mokhtarian & Tal 2013). By providing extensive information about the quality of restaurants, culinary review websites circulate such information. This may well increase the spatial extent of restaurant markets, because people are willing to travel further for restaurant visits if they face less uncertainty about their offer, while navigation devices make them easier to find. This may give rise to a complementary effect, because cities can draw better upon population in the surroundings. However, in places not too distant from large cities, an increased spatial extent of restaurant markets will entail a greater increase in consumer potential, compared to places in scarcely populated areas. This affects the location choice of new restaurants, for whom smaller places in the vicinity of larger ones have become more attractive. Evidence from Couture (2013) shows that almost all benefits of density in the restaurant market arise from the fact that people living in dense urban areas visit more restaurants, rather than from travel time savings. In the same manner, the abundance of information on the internet may induce people to travel further for restaurant visits, rather than to visit nearby restaurants more often.

This spillover mechanism may give body to the claims of several authors that the traditional benefits of urban size are increasingly substituted by 'borrowed size' (e.g. Phelps *et al.* 2001; Meijers 2007; Meijers & Burger 2017). This literature suggests that higher-order functions are increasingly found in places that are smaller than (central place) theory would suggest. They argue that the central place hierarchy of functions between cities – in which the most populated places tend to have the most higher order functions – is declining, in favour of stronger, more complex and complementary relationships between cities causing a decoupling of size and function.

To investigate the existence and interactions of the proposed mechanisms (substitute, complement, spatial spillover effect) we focus on two relationships. First, to investigate whether there is predominantly substitution or complementarity between online reviews and agglomeration economies of variety, we estimate the effect of online review intensity on cuisine variety, and we assess whether this effect is greater in larger or in smaller places. Second, to investigate whether online reviews enable places in the vicinity of larger cities to borrow size, and thus sustain a greater variety of cuisines than one would expect given their size, we examine to what extent the effect of online reviews on cuisine variety depends on distance to the nearest population centre.

DATA

Background – The history of restaurant cuisine variety in the Netherlands started in cities. The first Chinese restaurant in the Netherlands was opened in 1920 in Rotterdam, and the first Chinese restaurant that was aimed at Dutch customers was opened in 1928 in Amsterdam.[3] An excess of Chinese cooks during the economic crisis of the 1930s, and the increasing demand for Asian food by colonists returning from Indonesia stimulated the subsequent rise of Chinese restaurants: by 1945 there were 30 Chinese restaurants in the Netherlands, and by 1965 there were 225, of which many advertised themselves as Chinese-Indonesian (van Voskuilen 2013). Other ethnic cuisines followed during the 1960s and 1970s, as a result of labour migration from southern Europe (Italian, Greek, Spanish, Turkish) and decolonisation (Surinam).

Next to the specificities related to trade, colonialism, and work migration, there are a few other peculiarities concerning restaurant cuisine variety in the Netherlands. First, this market may be particularly prone to diversification because of a weak national food identity (DeSoucey 2010; Terhorst & Erkuş-Öztürk 2018). Indeed, the limitations of Dutch cuisine have led to many crossovers with other cuisines, most notably French. Second, the geography of restaurant variety in the Netherlands is not only shaped by the market. In the 1980s, the Dutch Ministry of Economic Affairs devised special rules that allow maximally one foreign owned Chinese-Indonesian restaurant for each 10,000 inhabitants in a municipality (Koopman 2002). Similar rules continue to apply nowadays: new migrants that apply for a permit in the Netherlands need to fulfil several characteristics that show that they provide a genuine merit to the Dutch economy.[4] EU citizens, on the other hand, have the freedom to start a business in the Netherlands since the Rome Treaty,[5] conditional on some provisions. De Lange (2016) notes that, due to trade agreements, entrepreneurs from Japan and the United States are almost as privileged as EU citizens in this respect. Finally, there are several other notable cuisine varieties in the Netherlands, not necessarily related to decolonisation, large-scale immigration or specific trade agreements, but rather to globalisation. These include Argentinian steakhouses, Mexican *cantinas*, Indian curry houses, and Thai and Vietnamese restaurants. Recent research into the Dutch restaurant industry calls attention to the role of urbanisation and gentrification in the continuing growth and diversification of this market (Terhorst & Erkuş-Öztürk 2018), and in the changing geography of haute cuisine restaurants (Boterman 2018).

Measuring cuisine variety – To study the current dynamics in the geography of cuisine variety in the Netherlands, we collected data on the universe of restaurants in the Netherlands, in 2000 and 2016, subdivided into 20 cuisine categories that broadly refer to different nationalities. The data are provided by HorecaDNA, and is constructed using the business registry of the Dutch Chamber of Commerce (Kamer van Koophandel). The information is available at the 4 digit postcode level (9 km^2 on average), and also includes the number of inhabitants at this scale. We recoded the data to the level of places (villages, towns, and cities in the Netherlands). There are 2,456 such settlements in the Netherlands. Population data is available for all places with more than 100 inhabitants, and Amsterdam had the largest population (747,725) in 2016. Summary statistics of these data are in Appendix Table A1. For the main analysis we use the same data on the number of cuisines in settlements, but only for the year 2016. Here we consider it as a continuous measure of cuisine variety. Figure 2 shows the distribution of this variable.

While this categorisation of 20 cuisine types is not exhaustive, and only measures variety across (groups of) nationalities, it is the only categorisation that covers all restaurants in the Netherlands, and it is consistent across places. We found that this categorisation correlates highly (0.9405) with a measure of cuisine variety based on 92 cuisine types, calculated from the Iens.nl data rather than from registry data. We do find that our measure of cuisine variety underestimates variety in places with the highest variety. Therefore, in our sensitivity analysis we check whether our results change when we exclude large cities with a high variety.

Measuring information technology – We measure information technology as the relative amount of online information on local restaurants, for each place in our dataset. We do this by calculating the share of restaurants in a place with at least one review on Iens.nl. Given the prominence of Iens.nl at the time of collecting the data (see Figure 2), we argue this is a reasonable proxy for online presence across all online channels. We scoured the entire website, consisting of georeferenced information of 21,795 Dutch restaurants, on 8 September 2016. Together with the detailed information on the total amount of restaurants in a settlement we are thus able to calculate the share of reviewed restaurants.[6] Figure 3 shows the distribution of this variable.

The indicator for the share of reviewed restaurants may depend on the turnover rate

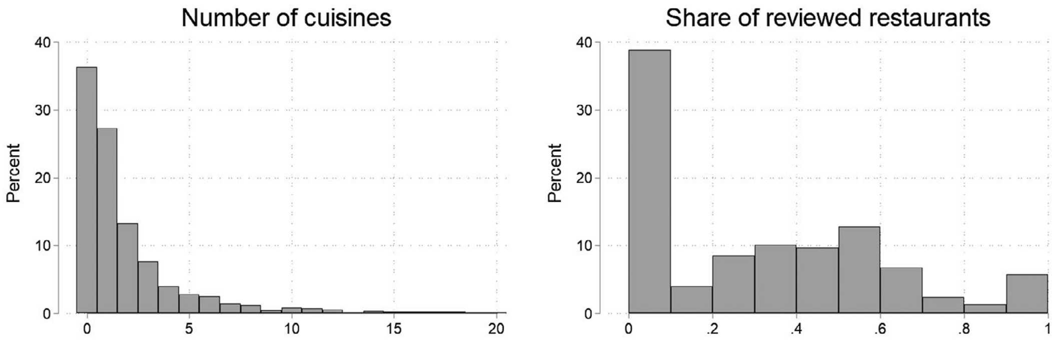

Figure 2. *Histogram of the number of cuisines and the share of reviewed restaurants.*

of restaurants. This may bias our results if the turnover rate is related to variety. One could indeed argue that vivid places with a high cuisine variety probably have a higher turnover rate. Since brand new restaurants may not be present on Iens.nl immediately, we run the risk of underestimating information technology presence in places with the most variety. This will bias our results downward, so in this sense our estimates may be seen as a lower bound of the real effect. We do believe that the extent of this bias will be limited, because in 2016 Iens.nl deleted reviews that were older than 4 years.

Data description – We enrich the data with demographic composition characteristics from Netherlands Statistics (CBS). We include household size, household income, the share of high educated, young and old people, and the share of western and non-western foreigners. For household income and the share of higher educated, data from 2016 is missing, and we use the income level of the nearest preceding year available (2012). Information on the share of high educated people is only available at the municipality level, and only for the year 2015. Netherlands Statistics' definition of western foreigners refers to persons of whom at least one parent is born outside of the Netherlands, in either Europe (excl. Turkey), North America, Oceania, Indonesia or Japan. Other foreigners include people with at least one foreign born parent from any other country. Furthermore we use data on the amount of hotel beds (also from HorecaDNA.nl).

The summary statistics are presented in Table 1. Dutch places have a modest variety of cuisines on average, with 1.88 cuisines on 20.16 restaurants. In 2000 the average number of cuisines was 1.56 so there has been a slight increase. The average share of reviewed restaurants is 30 per cent (43% for all settlements with at least one restaurant), with considerable variation between places, and about 0.02 reviews per capita. In Appendix Table A2 we report summary statistics for the part of the sample for which the (historical) number of cuisines and the average household income are greater than zero, because we only use this set of data in the analysis. This leaves us 1,280 places, about 57 per cent of all places. Arguably, excluding all (genuinely tiny) places without restaurants should not be problematic, because the share of reviewed restaurants is only informative if there is at least one restaurant.

METHODS

Empirical approach – We begin our empirical analysis by exploring how cuisine variety changed across places, between 2000 and 2016. We use maps of cuisine variety, and we plot the smoothed relationship between population and cuisine variety for both years, to examine the geographical pattern of changes in cuisine variety, and to what extent it varies with the size of local population. As during this period there were many major IT advances (broadband internet, Wi-Fi, 3G, smartphones, etc.), the patterns we find can give us some initial expectations about how IT affected cuisine variety.

In the exploratory part we also investigate to what extent the distribution of cuisines

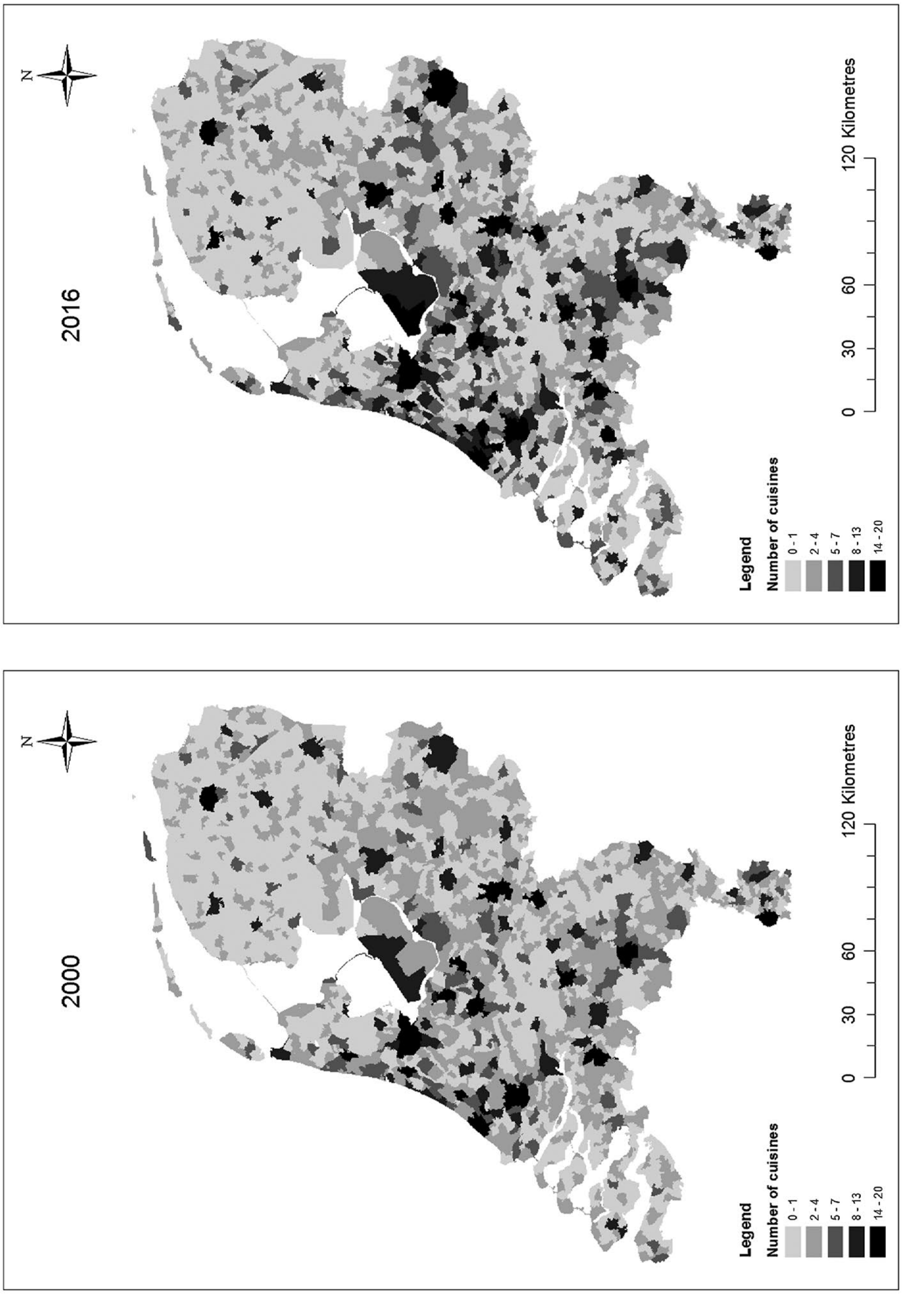

Figure 3. *Maps of cuisine variety.*

Table 1. *Summary statistics.*

Variables	(1) Mean	(2) Sd	(3) Min	(4) p50	(5) Max
Number of cuisines	1.881	2.814	0	1	20
Number of cuisines 2000	1.557	2.268	0	1	20
Number of restaurants	20.16	112.7	0	5	4,088
Number of restaurants/capita	0.00351	0.00499	0	0.00240	0.0741
Hotel beds/capita	0.0232	0.106	0	0	2.477
Share of reviewed restaurants	0.301	0.299	0	0.286	1
Number of reviews/capita	0.0196	0.0561	0	0.00200	0.992
Population	7,540	28,831	100	1,690	747,725
Population density	0.397	0.646	0.00478	0.165	6.415
Area (hectare)	1,517	1,641	18.92	1,070	26,058
Average household size	2.393	0.216	1.670	2.380	3.420
Average household income	34,352	10,616	0	36,300	81,800
Share high educated	24.29	7.046	0	23.70	96.80
Share young	0.163	0.0306	0.0345	0.162	0.349
Share old	0.197	0.0459	0.0333	0.194	0.581
Share western foreign	0.0653	0.0476	0	0.0549	0.624
Share nonwestern foreign	0.0306	0.0411	0	0.0204	0.675
N	2,249				

across places conforms to a *central-place hierarchy*, according to which the rarest cuisines are found in places that have all other, more common cuisines. For this purpose we use a hierarchy diagram and a hierarchy statistic, initially proposed by Mori *et al.* (2008). The hierarchy statistic captures the share of cuisine-place pairs for which all places with more cuisines, also have the respective cuisine. Following Schiff (2015) we test the null hypothesis that cuisines are randomly assigned across places. We do this by running 1,000 simulations in which we randomly draw cuisine types for every settlement, based on the observed number of cuisines, estimating the distribution of the hierarchy statistic in a counterfactual situation in which a place with only one cuisine should not be more likely to have an Italian cuisine, than a Japanese cuisine.

The next step is to investigate the relationship between the share of reviewed restaurants and local cuisine variety. The idea is that if relatively more restaurants in a place are reviewed at this website, online information dissemination is more effective, and demand increases, spurring the entry of new varieties. Following Schiff (2015) and Berry and Waldfogel (2010), the dependent variable is the logarithm of the number of cuisines. The independent variable that denotes population is also in logs, so the resulting coefficient can be interpreted as an elasticity. The specification is as follows:

$$\log(C_i)=\alpha+\beta\log\left(Pop_i\right)+\gamma\log\left(Area\right)+\delta R_i + \kappa X_i+\epsilon_i, \quad 1$$

where C is the number of cuisines. We add an interaction between the share of reviewed restaurants and population to assess whether the effects of reviews on variety are greater in larger or in smaller places. Our conclusion depends on the value of $\partial^2 E\left[\log(C)\,|\log(Pop),R\right]/\partial R\partial\log\left(Pop\right)$. If this is positive, IT and local population complement each other in generating local variety, if this is negative the effect of IT on local variety is greater in smaller places.

Finally we investigate whether IT can be linked to increased spillovers between places. This is the third mechanism through which IT may impact agglomeration. Here we allow the effect of IT on cuisine variety to vary across distance from nearby population centres ($Dist_i$), using different population thresholds that define such a centre

(20k, 50k, and 100k). If IT is associated with spillovers between places – that is with increased demand from nearby places – we expect the effects of IT to be greater in the vicinity of large population centres, namely, $\partial^2 E[\log(C)\,|R,Dist]\,/\partial R \partial Dist < 0$.

Identification issues – We aim to measure the causal effect of the share of reviewed restaurants on cuisine variety. However, this relationship poses several identification problems, including a potential bias due to omitted variables (Angrist & Pischke 2008). In our regression models therefore, we control for a variety of socio-demographic variables. In addition, we include the number of hotel beds per capita to control for the effects of elevated demand due to local tourism.

There remain other issues. Severe local competition may for instance both trigger restaurants to differentiate their cuisine from other restaurants, and to register at online review databases. Evidence from the management literature indeed shows that the extent of online information about products can be related to the extent of competition (Li *et al.* 2011). We resolve this issue by taking two steps. First, by focusing on the share of *reviewed* restaurants we have an independent variable that cannot be easily controlled by restaurant owners. While restaurant owners may in principle register their restaurant at Iens.nl, reviews have to come from customers, and registration at Iens.nl is not required to leave a review.[7] Second, we control for the extent of local competition by including the number of restaurants per capita as a proxy.

There also exists the possibility of selection. Online reviewers may for instance be disproportionately attracted to cities with a culinary culture, with a lot of restaurants and different cuisines. Following this reasoning, typical 'foodie cities' would have both more cuisines and more reviewed restaurants, without there being a causal relation from IT to variety. An ideal strategy to control for such time-invariant characteristics of places would be to use temporal variation to estimate the effect. Unfortunately we only have cuisine data at the level of places until 2016, and Iens.nl data starting 2016. Therefore we employ an alternative strategy in which we include the cuisine count from 2000 as a proxy for 'culinary culture'. The key assumption here is that variation in the share of reviewed restaurants is random, conditional on cuisine variety in 2000 and the other control variables. Since the Iens.nl website started in 1999, cuisine variety in 2000 is likely unaffected by Iens.nl reviews.

Finally there is the issue of reverse causality. This would be the case if greater variety in cuisines would trigger consumers to leave reviews, or alternatively, if restaurants with rare cuisines are somehow more attractive to review. The ideal strategy to deal with this type of bias is to find an instrumental variable that only affects cuisine variety through its effect on the share of reviewed restaurants. We experimented with a number of candidates, including the number of reviews per capita, the penetration of glass-fibre internet, and distance to Amsterdam (the city where Iens.nl started). We could not find an instrument that was both strong and clearly exogenous to cuisine variety. We also experimented with a model based on time variation in reviews and variety, using municipality level data between 2016 and 2017, but there was not enough variation for any significant results. While we are confident that controlling for 'foodie cities' captures a large part of the reverse causality problem, it cannot be ruled out that changes in cuisine variety between 2000 and 2016 affected the share of reviewed restaurants rather than the other way around. Our results remain sensitive to this issue, which would bias our estimates upwards.

We ignore potential reverse causality between cuisine variety and local population because earlier results on the relationship between population and cuisine variety suggest that controlling for reverse causality does not alter results (Schiff 2015), in line with results from for example, Chen and Rosenthal (2008) who find that local amenities, among which cuisine variety, are in fact a minor pull-factor of cities compared to business factors.

RESULTS

In this section we proceed with the empirical analysis. First we explore changes in the geographical distribution of cuisines between 2000 and 2016. Then we estimate the effect of the share of reviewed restaurants on cuisine variety, and we investigate to what extent this effect varies across smaller and larger places, and with distance from population centres. Finally, we subject our results to several sensitivity checks.

Cuisine variety across places – Figure 4 shows the geographic distribution of cuisine variety over Dutch settlements. This map clearly shows that cuisine variety rose countrywide between 2000 and 2016, and that cuisine variety seems to have radiated out from places that had a varied supply of cuisines in 2000. We examine whether the (observational) relationship between municipal population and cuisine variety has significantly changed during this period. Figure 5 depicts the fitted relationship between (the logarithm of) population and cuisines, using a local polynomial function. For places with populations between 1,000 and 100,000, cuisine variety has increased significantly.

Figure 6 shows hierarchy diagrams for the year 2000 and 2016. Here cuisine-place pairs are ranked according to (1) the rarity of the cuisine (y-axis, 0 is rarest), and (2) the amount of cuisines in a place (x-axis). Both years show a clear hierarchical pattern in which rarer cuisines are more likely to be present in places that have more cuisines. Following Mori *et al.* (2008), we use the term 'hierarchy event' for cuisine-place pairs for which all higher ranked places also have the respective cuisine, and 'non-hierarchy event' for all other pairs. The difference in hierarchy for both years can be assessed using a hierarchy statistic that denotes the share of hierarchy events. This is equivalent to the share of dots in the graph for which all 'slots' on the right are occupied. In 2000 23.2 per cent of cuisine-municipality pairs were hierarchy events, versus 18.2 per cent in 2016. While both years show a significant hierarchy compared to the hierarchy that results from a random cuisine distribution (7.1%), the difference in hierarchy between 2000 and 2016 is significant (p = 0.000) and this means that the functional hierarchy cuisine variety across cities has decreased during this period.

We draw three conclusions from this exploratory analysis. First, the finding that cuisine variety seems to have grown most extensively near places where variety was already high is in line with the hypothesis that the advent of IT in the restaurant industry led to an increase in the geographical extent of restaurant markets, and increased spillovers between places. Second, the functional form, and size of the relationship between local population and variety did not change dramatically during the study period, which indicates that local population is still a major factor explaining cuisine variety. Finally, the finding that the hierarchical distribution of cuisines across places has decreased may indicate that IT has made it possible for (residents of) nearby places to make better use of complementarities in the supply of cuisines.

Substitution or complementarity – Table 2 presents the results of regression models based on equation (1). It should be noted that the dependent variable is in logs, so a dR increase in the share of reviewed restaurants leads to a $(e^{dR*\delta}-1)*100\%$ increase in cuisine variety. Column (1) reports a coefficient of 0.254 for the share of reviewed restaurants, which means that a 0.25 increase (about a standard deviation) leads to a 6.5 per cent increase in cuisine variety. This is comparable to the effect of increasing the amount of inhabitants in a settlement with 29 per cent. We find positive effects of restaurants per capita, and the number of cuisines in 2000, so both competition and 'culinary culture' seem closely related with cuisine variety. The effect of hotel beds per capita is only significant at the 10 per cent confidence level.

Results from column (2), in which we use population density instead of population and area separately, result in similar findings, although it seems that variables that distinguish urban from non-urban environments (such as the share on non-western foreigners and cuisine count in 2000) matter more in this regression. According to this model a 0.25 increase in the share of reviewed restaurants results in a 5.4 per cent increase in cuisine variety. The effect of population density suggests that all else equal, places that are twice as dense have about 7 per cent more cuisine variety.

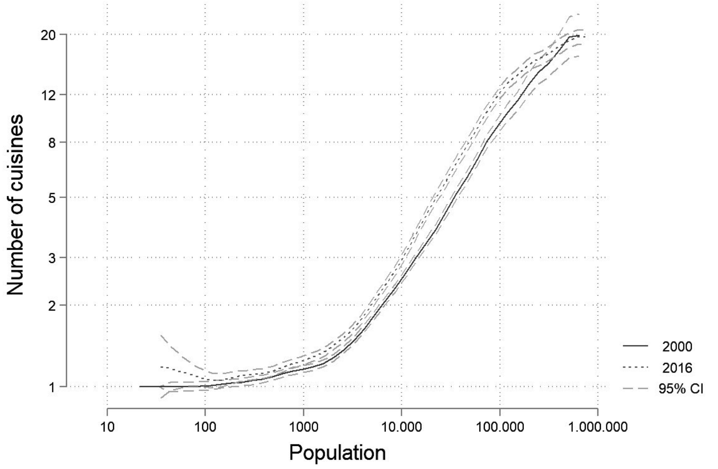

Figure 4. *Non-parametric fit of the relationship between population and cuisine variety in Dutch places in 2000 and 2016.*

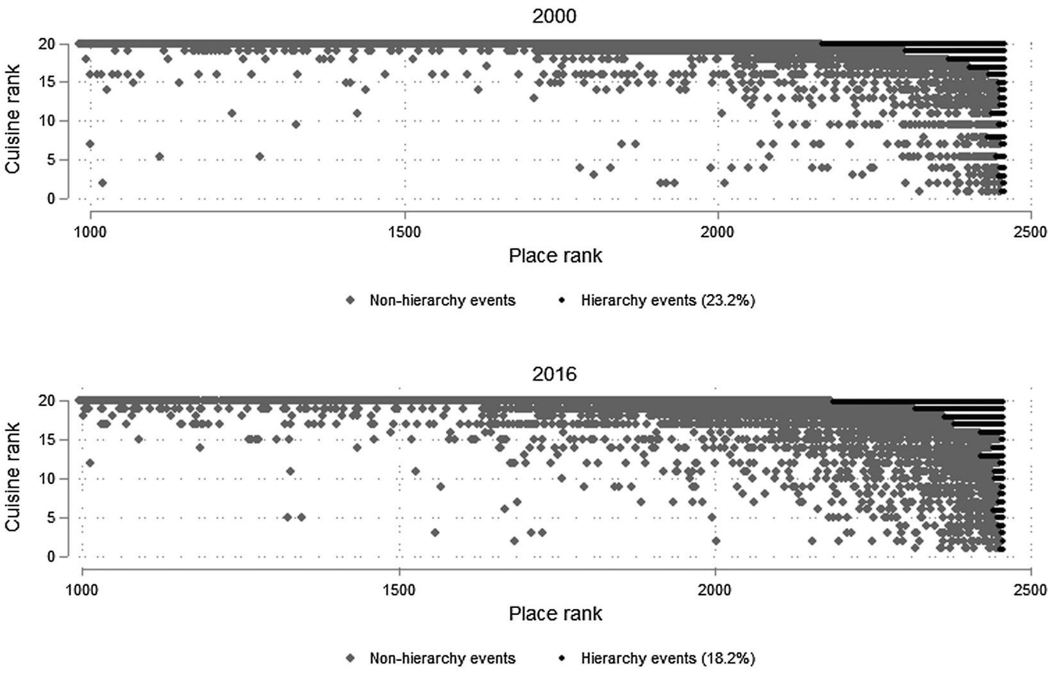

Figure 5. *Hierarchy diagrams, 2000 and 2016. The observations are instances in which a cuisine is present in a place. Along the y-axis, cuisines are ranked according to their year specific rarity (where 1 denotes the rarest cuisine). Along the x-axis, places are ranked according to the number of cuisines they have. The place rank starts at 996, because 995 places have no cuisines at all.*

In columns (3) and (4), we allow for a linear interaction between the share of reviewed restaurants and population and population density respectively. In these models population and population density are centred around their mean, for ease of interpretation. The resulting estimates are shown graphically in Figure 7, and they are unequivocal:

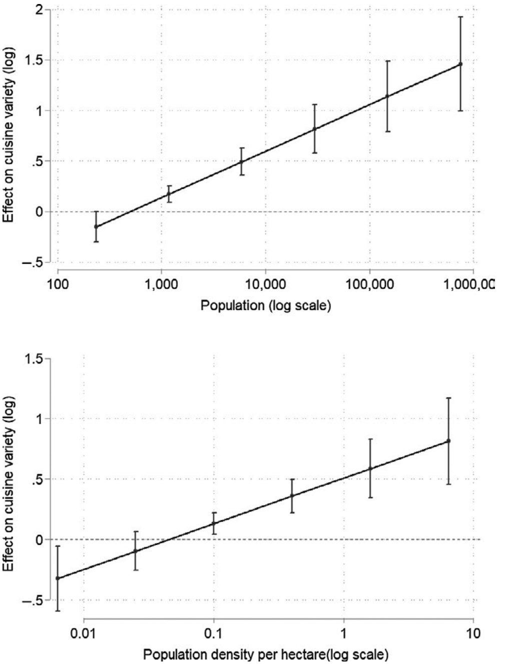

Figure 6. *Marginal effects of the share of reviewed restaurants across population (l) and population density (r). The dots represent the point estimates, the vertical lines represent the 95% confidence intervals, and the dashed line represents 0.*

the effect of the share of reviewed restaurants is higher in both larger and denser places. Column (3) provides a range of estimates from –0.15 in the smallest place, to 1.45 in the largest. In column (4) the estimates range from –0.32 in the least dense places to 0.81 in the densest. The emerging pattern suggests a complementary relationship between the cities and IT when it comes to variety in the restaurant market.

Spillovers – Recall that Figures 4, 5 and 6 provided exploratory evidence for the existence of agglomeration spillovers, as cuisine variety seems to grow most near larger places and that the relationship between size and cuisine variety was strong, but declining. Here, we estimate models in which we let the effect of the share of reviewed restaurants vary according to the distance to the nearest population centre. We include interactions with the share of reviewed restaurants and quintile categories of distance to the nearest centre, and we vary the minimum size of these population centres between 20,000, 50,000 and 100,000 inhabitants. The results of these models are shown graphically in Figure 7, and in Appendix Table A3. Panel (a) shows the decay pattern of the effect as it varies over distance from places with at least 20,000 inhabitants. A steep decay pattern is visible that plateaus after 8 kilometres. The effect of reviewed restaurants thus vitally depends on proximity to population centres. Panels (b) and (c) show the results of interactions with distance to centres of 50,000, 100,000 inhabitants or more, respectively. As we increase the threshold population that defines a population centre, the decay pattern becomes weaker. However with all definitions, the effect is consistently higher in the closest 2 quintiles than in the two farthest quintiles. These results favour the idea that part of the effect of online review intensity on cuisine variety is due to spatial spillovers.

Table 2. *OLS Regression models cuisine count and reviewed restaurants.*

	(1)	(2)	(3)	(4)
Share of reviewed restaurants	0.254***	0.211***	0.404***	0.295***
	(0.0442)	(0.0469)	(0.0570)	(0.0576)
× population (log)			0.200***	
			(0.0368)	
× population density (log)				0.164***
				(0.0442)
Population (log)	0.225***		0.146***	
	(0.0163)		(0.0206)	
Area (log)	0.0385***		0.0365**	
	(0.0149)		(0.0144)	
Population density (log)		0.0722***		0.00508
		(0.0145)		(0.0227)
Restaurants/capita	27.16***	13.70***	28.48***	14.37***
	(3.182)	(3.044)	(3.084)	(3.074)
Number of cuisines 2000 (log)	0.576***	0.843***	0.551***	0.830***
	(0.0291)	(0.0225)	(0.0296)	(0.0231)
Share young	0.585	1.154*	0.441	0.970
	(0.575)	(0.602)	(0.567)	(0.605)
Share old	0.278	0.172	0.367	0.195
	(0.307)	(0.334)	(0.302)	(0.334)
Average household size	−0.187	−0.115	−0.161	−0.0974
	(0.114)	(0.122)	(0.111)	(0.120)
Average household income	0.0455	−0.00251	−0.0170	−0.0575
	(0.127)	(0.135)	(0.124)	(0.136)
Share western foreign	−0.0889	−0.205	−0.0864	−0.214
	(0.204)	(0.223)	(0.203)	(0.221)
Share non-western foreign	0.397	1.342***	0.235	1.273***
	(0.296)	(0.401)	(0.291)	(0.389)
Share high educated	0.00146	0.000569	0.000822	6.42e−05
	(0.00152)	(0.00163)	(0.00154)	(0.00162)
Hotel beds/capita	−0.253*	−0.144	−0.254**	−0.122
	(0.129)	(0.152)	(0.122)	(0.153)
Constant	−0.672	0.126	−0.0713	0.674
	(1.202)	(1.231)	(1.167)	(1.248)
Observations	1,280	1,280	1,280	1,280
R-squared	0.836	0.803	0.840	0.806

Notes: Dependent variable: Cuisine count (log). Robust standard errors in parentheses. $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$. Population (log) and Population density (log) are mean-centred, for ease of interpretation of the main effects.

Sensitivity analysis – In this subsection we submit our results to several sensitivity checks. Table 3 presents the sensitivity analysis for which we use Table 2, column (3) as a baseline, so we include an interaction between the share of reviewed restaurants and population.

One potential drawback of the analysis conducted in the previous subsection is the limited categorisation of cuisines in the dependent variable (20 categories). This may lead to measurement error, especially in the largest cities that have close to 20 cuisines. In column (1) we check whether our results are not dependent on observations from these largest cities. Therefore we limit the sample to places that do not exceed 100,000 inhabitants. The results are similar to the baseline estimate, with a comparable interaction between IT usage and population.

In column (2) we use an alternative measure of review website penetration: the

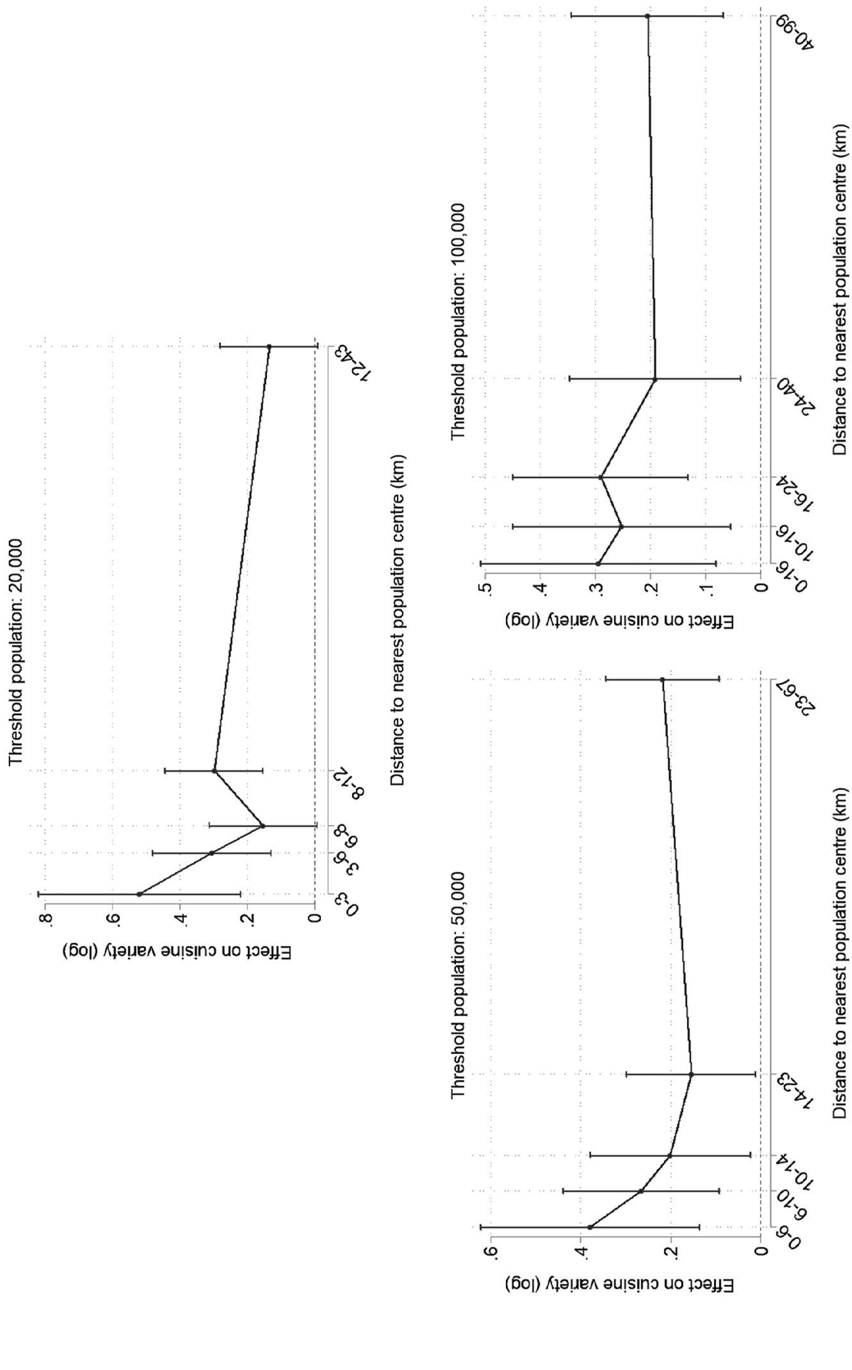

Figure 7. *The effect of the share of reviewed restaurants and distance to population centres. The dots represent the point estimates, the vertical lines represent the 95% confidence intervals, and the dashed line represents 0.*

Table 3. *Sensitivity regressions population.*

	(1)	(2)	(3)
Variables	Pop<=100k	Reviews/capita	Municipality
Share of reviewed restaurants	0.409***		0.473***
	(0.0552)		(0.130)
× population (log)	0.228***		-0.273
	(0.0362)		(0.166)
Reviews per capita		0.767**	
		(0.374)	
× population (log)		0.340**	
		(0.158)	
Population (log)	0.133***	0.210***	0.407***
	(0.0204)	(0.0162)	(0.0900)
Control variables	Yes	Yes	Yes
Observations	1,258	1,280	389
R-squared	0.824	0.832	0.792
F-statistic			
Endogeneity test (p)			

Notes: Dependent variable: Cuisine count (log). Robust standard errors in parentheses. ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$. Population (log) is mean-centred, for ease of interpretation of the main effects.

number of reviews per capita. In the average city, a standard deviation (about 0.06) increase in the number of reviews per capita, results in a 4.7 per cent increase in cuisine variety, which is comparable to the results in the previous subsection. The estimated interaction term is positive, in line with the other models.

In column (3) we check whether our results are sensitive to choosing another geographical scale of analysis. In the previous regression models cuisine variety was analysed at the level of places. Arguably, this is a lower bound of the geographical extent of restaurant markets. Therefore we analyse cuisine variety at the level of municipalities (covering 86 square kilometres on average). The summary statistics of these data are in Appendix Table A4. We find a positive effect of the share of reviewed restaurants on cuisine variety that is somewhat greater than the baseline estimate. An increase of 0.25 in the share of reviewed restaurants leads to a 12.5 percent increase in cuisine variety (vs. 10.6% in Table 2 column (3)). At the municipality level the interaction term is insignificant. This result suggests that the interaction effect between size and information depends crucially on the spatial scale of analysis.

Several conclusions can be drawn from our sensitivity analysis. First, the notion that there is a positive and significant effect of online review intensity on cuisine variety is particularly robust to our sensitivity checks. Second, whether the effect of online information is greater in larger places depends crucially on the spatial scale at which the analysis is done. Finally, at the level of places, the positive interaction effect remains a robust finding.

CONCLUSION

In the literature it is often shown that while IT acts as a substitute for many urban benefits, IT also complements the variety economies of agglomeration, because a greater extent of online local information stimulates demand for local goods, thereby promoting the entry of new varieties (Sinai & Waldfogel 2004; Anenberg & Kung 2015). We find that IT usage in the restaurant market (reviews) has a significant and positive effect on local cuisine variety that increases with place size. This suggests a complementary relationship between agglomeration and IT, when it comes to local variety. However, the complementary relation between online information and variety decays with distance from large population centres, which indicates that IT allows places in the vicinity of these centres to 'borrow size' of their neighbours, and sustain a higher variety of cuisines. IT decreases spatial information frictions, and makes these places more accessible for residents of neighbouring areas. The complementarity between IT and local variety thus not only comes from more efficient information exchange, and increased local demand, but also from an increased geographical extent of markets.

We have three suggestions for further research into the link between IT and agglomeration. First of all, we identify a geographical effect of IT, referred to as 'borrowed size': agglomeration spillovers to smaller nearby places causing the increasing disconnection between size and function. However, conclusive evidence of this mechanism should ideally come from travel behaviour data that shows that (1) inhabitants of large towns are indeed travelling longer for consumption purposes, (2) this is particularly so for users of online platforms, and (3) this coincides with the penetration of online reviews. Second, our measure of reviewed restaurants only includes the entries on one website. For a long time Iens.nl was the market leading website, but there are rapid changes in the world of online culinary reviews, and information can now be found through various sources including Google Places, TripAdvisor, Facebook, and through personal blogs. While we feel that Iens.nl penetration may be a good proxy for the usage rate of all these sources, future measures of online information may have to take into account this increasingly scattered landscape. Third, variety increases may not benefit all consumers equally. Several scholars have proposed that high skilled individuals have a higher love of variety, and may thus benefit most (Adamson *et al.* 2004; Lee 2010). Future research may be aimed at finding out whether the benefits of IT have a skill-bias.

The results in this paper have multiple implications for strands of literature that do not focus on the effects of IT on agglomeration externalities of consumption. This paper is the first to estimate the relationship between cuisine variety and population size in a European context with many small settlements. The estimated elasticities of cuisine variety with respect to population are between 0.133 and 0.407. This is lower than the elasticity estimates reported by Schiff (2015) for the US (between 0.35 and 0.49), most likely due to the inclusion of smaller places. Relatedly, there seems to be a central place pattern to the distribution of cuisine varieties among Dutch municipalities. However, by adding a temporal dimension to this relationship, we show a declining relationship between size and variety, and a decreasing hierarchy among settlements. This may indicate that central place theory is becoming less useful in describing spatial patterns of consumption, and our results strengthen the idea that the focus should move more towards complementarity instead of hierarchy (Meijers 2007).

Finally, our results call for a renewed debate on the effects of IT on agglomeration. Substitution, complementarity, and spillover mechanisms are most likely present in the interaction between IT and other aspects of agglomeration, including face-to-face contact, knowledge spillovers, sharing of public goods and other amenities.

Acknowledgement

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Notes

1. Growing demand does not necessarily lead to higher product variety. Shaked and Sutton (1987) propose that this depends crucially on whether quality is predominantly produced with fixed rather than variable costs. In the former case quality tends to increase with market size while the industry remains concentrated, in the latter case the range of qualities tends to increase with market size. Berry and Waldfogel (2010) take this prediction to the data, and find that newspaper markets tend to remain concentrated, while restaurant markets offer more variety with increasing market size. Schiff (2015) shows that the relationship between market size and variety holds both with a general 'love of variety', and in the case that every consumer has

a preferred restaurant type, given that there is a taste hierarchy.

2. Since September 2016, Iens.nl has been taken over by TripAdvisor. This explains the sudden bifurcation of the two trends in Figure 1 around the end of 2016.
3. 'Cheung Kwok Low' was the first Chinese restaurant in the Netherlands, with a clientele consisting of Chinese sailors (http://www.isgeschiedenis.nl/nieuws/de-geschiedenis-van-de-afhaalchinees-in-nederland/). 'KongHing' in Amsterdam was the first restaurant that actively aimed to serve Dutch customers (http://www.iisg.nl/collections/chinezen-zeedijk/chinezen-nl.php).
4. "Wezenlijk Nederlands belang", see Artikel 13 sub b Vreemdelingenwet 2000.
5. Treaty Establishing the European Economic Community, 25 March 1957.
6. Because we measure the universe of restaurants at the beginning of 2016, and the number restaurants registered at Iens.nl more than half a year later, there may be a slight measurement error. Indeed, 23 out of 2,249 places show a share of reviewed restaurants higher than 1, which we normalise to 1. This does not affect the results.
7. A potential bias may still exist if Iens registration lowers the bar for people to leave a review, and restaurant owners with rare cuisines may push customers more to leave reviews. As we control for competition, this bias is only relevant in case of registrations by restaurants not triggered by competition.

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APPENDIX

Table 1. *Summary statistics cuisine data, 2000 and 2016.*

	2000				2016			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Variables	Mean	Sd	Min	Max	Mean	sd	Min	Max
Number of cuisines	1.434	2.210	0	20	1.737	2.739	0	20
Cuisines								
Dutch-French	2.410	7.910	0	213	2.116	7.623	0	247
Italian	0.401	3.469	0	152	0.562	5.196	0	231
Greek	0.145	0.663	0	12	0.155	0.691	0	12
Turkish	0.0651	0.784	0	27	0.120	1.459	0	49
Southern-European	0.0289	0.452	0	20	0.140	1.244	0	49
Spanish-Portuguese	0.0314	0.488	0	20	0.0656	0.737	0	31
Eastern-European	0.0322	0.273	0	7	0.0151	0.159	0	5
Other European	0.0550	0.432	0	13	0.143	0.993	0	36
International	0.195	2.340	0	108	0.591	5.834	0	255
Chinese-Indonesian	0.896	4.676	0	160	0.730	3.532	0	110
Japanese	0.0269	0.413	0	17	0.142	1.466	0	61
Other Asian	0.0305	0.679	0	32	0.0660	1.106	0	49
Thai	0.0415	0.709	0	32	0.0599	0.916	0	39
Indian	0.0334	0.657	0	30	0.123	1.501	0	60
Argentinian	0.0350	0.514	0	23	0.0566	1.157	0	56
Mexican	0.0371	0.370	0	12	0.0350	0.402	0	17
American (US)	0.0375	0.254	0	7	0.0399	0.319	0	10
Surinamese	0.0200	0.405	0	14	0.0248	0.471	0	18
Other American	0.0159	0.236	0	10	0.0261	0.377	0	16
Other Foreign	0.0334	0.413	0	17	0.0525	0.718	0	29
N	2,456				2,456			
Population	6,501	24,747	0	645,650	6,924	27,688	0	747,725
N	2,439				2,452			

Table A2. *Summary statistics regression sample*

	(1)	(2)	(3)	(4)	(5)
Variables	Mean	Sd	Min	p50	Max
Number of cuisines	3.176	3.147	1	2	20
Number of cuisines 2000	2.594	2.534	1	2	20
Number of restaurants	33.71	147.9	1	11	4,088
Number of restaurants/capita	0.00388	0.00493	0.000292	0.00263	0.0651
Hotel beds/capita	0.0285	0.0934	0	0.00485	1.195
Share of reviewed restaurants	0.417	0.238	0	0.427	1
Number of reviews/capita	0.0273	0.0629	0	0.00891	0.992
Population	12,437	37,477	235	4,050	747,725
Population density	0.580	0.787	0.00629	0.275	6.415
Area (hectare)	1,956	1,976	20.86	1,453	26,058
Average household size	2.337	0.199	1.670	2.330	3.334
Average household income	36,727	4,592	25,200	36,300	81,800

Continued

Table A2. *(Continued)*

	(1)	(2)	(3)	(4)	(5)
Variables	Mean	Sd	Min	p50	Max
Share high educated	25.29	7.686	0	24.90	96.80
Share young	0.161	0.0275	0.0545	0.161	0.349
Share old	0.207	0.0436	0.0533	0.204	0.451
Share western foreign	0.0733	0.0479	0	0.0640	0.583
Share nonwestern foreign	0.0407	0.0460	0	0.0263	0.636
N			1,280		

Table A3. *Regression models spatial spillovers.*

	(1)	(2)	(3)
Share of reviewed restaurants			
× distance quintile I	0.519***	0.357**	0.301**
	(0.153)	(0.139)	(0.121)
× distance quintile II	0.304***	0.316***	0.211**
	(0.0899)	(0.0874)	(0.106)
× distance quintile III	0.152*	0.247***	0.271***
	(0.0821)	(0.0922)	(0.0816)
× distance quintile IV	0.298***	0.147**	0.248***
	(0.0740)	(0.0749)	(0.0804)
× distance quintile V	0.134*	0.233***	0.264***
	(0.0740)	(0.0658)	(0.0730)
Distance quintile II	0.0721	0.0126	0.0193
	(0.0821)	(0.0776)	(0.0747)
Distance quintile III	0.173**	0.0481	0.0282
	(0.0818)	(0.0765)	(0.0723)
Distance quintile IV	0.105	0.0625	0.0479
	(0.0806)	(0.0750)	(0.0716)
Distance quintile V	0.176**	0.104	0.0442
	(0.0813)	(0.0749)	(0.0724)
Population (log)	0.229***	0.231***	0.230***
	(0.0171)	(0.0169)	(0.0173)
Control variables	Yes	Yes	Yes
Threshold population	20,000	50,000	100,000
Observations	1,280	1,280	1,280
R-squared	0.837	0.837	0.836

Notes: Dependent variable: Cuisine count (log) Robust standard errors in parentheses. ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

Table A4. *Summary statistics municipality data.*

Variables	(1) Mean	(2) Sd	(3) Min	(4) p50	(5) Max
Number of cuisines	6.813	3.886	1	1	20
Number of cuisines 2000	5.218	3.416	0	0	20
Number of restaurants	102.2	244.4	2	2	3,857
Number of restaurants/ capita	0.00241	0.00236	0.000612	0.000612	0.0250
Hotel beds/capita	0.0175	0.0622	0	0	0.942
Share of reviewed restaurants	0.494	0.148	0.0833	0.0833	1
Number of reviews/ capita	0.0206	0.0353	7.81e-05	7.81e-05	0.493
Population	43,536	67,610	919	919	833,624
Area (hectare)	8,635	7,507	702.6	702.6	45,979
Average household size	2.293	0.183	1.600	1.600	3.300
Share high educated	25.97	8.191	0	0	96.80
Share young	0.165	0.0206	0.109	0.109	0.290
Share old	0.200	0.0313	0.0884	0.0884	0.310
Share western foreign	0.0806	0.0422	0.0144	0.0144	0.441
Share nonwestern foreign	0.0634	0.0549	0.0114	0.0114	0.376