ARE THERE "RATATOUILLE" RESTAURANTS? ON ANTICORRELATION OF FOOD QUALITY AND HYGIENE

Hisayuki Yoshimoto and Andriy Zapechelnyuk

Abstract. We study the empirical relationship between hygiene conditions in restaurants and their food quality rated by professional reviewers. Using evidence from the UK, we show that this relationship is negative and statistically significant. So, a higher food quality rating is generally associated with a less sanitary kitchen. We find that 3% of Michelin starred restaurants in our dataset have poor hygiene conditions, while the same is true for only 2% of non-Michelin starred restaurants. Our findings illuminate potential channels through which the anticorrelation between food quality and hygiene could be mitigated, which can be helpful for hygiene inspection design.

JEL Classification: L15, H75, D22, I18

Keywords: Food quality, restaurants, reviews, hygiene standards, food hygiene certification

Date: 3rd March 2020

Yoshimoto: Adam Smith Business School, University of Glasgow, University Avenue, Glasgow G12 8QQ, UK. *E-mail:* Hisayuki.Yoshimoto@glasgow.ac.uk.
Zapechelnyuk: School of Economics and Finance, University of St Andrews, Castlecliffe, the Scores, St Andrews KY16 9AR, UK. *E-mail:* az48@st-andrews.ac.uk.

The authors thank Toman Barsbai, Dakshina De Silva, David Jaeger, Margaret Leighton, Marco Manacorda, and Arjunan Subramanian for helpful comments and suggestions. Financial support from the Economic and Social Research Council Grant ES/N01829X/1 is gratefully acknowledged.

1. Introduction

All across the globe, when choosing where to have a meal, diners rely on food quality reviews. These reviews come from a variety of sources, from popular guidebooks (such as the Michelin Guide and Zagat) to consumer review websites (such as Tripadvisor and Yelp). Diners are after a quality meal experience, so the last thing they want is to end up sick with food poisoning. "Food hygiene when eating out" tops the list of public concerns related to food safety, according to the Biannual Public Attitudes Tracker Survey 2019 published by the UK Food Standards Authority.[1,2]

In this paper we investigate whether professional restaurant review scores are informative of hygiene conditions in restaurant kitchens. Particularly, we ask if there are *Ratatouille* restaurants: highly rated establishments with poor hygiene practices, a concept we name after a rat-infested gourmet restaurant featured in the animation movie "Ratatouille" (Pixar & Walt Disney Pictures, 2007).

To address this question, we use professional review data of UK based restaurants from two popular restaurant guides, *The Michelin Guide* and *The Good Food Guide*, as well as the hygiene certification data from the UK Food Standards Agency. Unlike consumer review-based sources (such as Tripadvisor and Yelp), professional reviewers have the capability to account for hygiene conditions in their reviews, suggesting that restaurants with higher professional review scores should have cleaner kitchens. However, the economics intuition says that there may be a substitution effect: a greater effort on higher food quality may come at the expense of the hygiene effort.

We show that there is a statistically significant conditional negative correlation between food quality rating and hygiene scores, thus confirming the economic intuition of the substitution effect. In particular, we find that 3% of Michelin starred restaurants in our dataset have poor hygiene conditions categorized as "Improvement Necessary" or worse, while the same is true for only 2% of non-Michelin starred restaurants. The conclusion is that restaurant review scores from the well-known guidebooks are indicative about food hygiene standards, but, unfortunately, in a negative way, which is likely to be misleading for consumers. The evidence that we found suggests that the restaurants' aspirations to be included in prestigious guidebooks appear to be

[1]Available here: https://www.food.gov.uk/about-us/biannual-public-attitudes-tracker

[2]For instance, in February 2019, a Michelin starred restaurant in Spain had a food poisoning incident, involving 29 people hospitalized and one death. Source: https://www.theguardian.com/world/2019/feb/21/woman-dies-after-eating-at-michelin-starred-restaurant-riff-valencia.

misaligned with the incentives to operate in foodborne disease free conditions, which raises concerns about consumer protection and public health.

Our estimation results provide a quantitative basis for the analysis of the relationship between the control variables and the hygiene generating process. These results can be useful for inspection authorities in understanding the incentive structure of restaurants, and can also be informative for designing hygiene inspection policies, such as the prioritization of inspections based on observable restaurant characteristics.

Our study focuses on high-end restaurants listed in popular guide books, rather than on the broader class of restaurants. One reason for this choice is data availability. While the hygiene data is available for all restaurants, our restaurant-specific control variables are obtained from the Good Food Guide. Another reason is that asymmetric information plays a more dramatic role in the high-end product sector: buyers tend to form high expectations for multi-dimensional product characteristics based on the available information, such as professional evaluation scores. However, in many high-end products, some quality dimensions are more salient to buyers than others, leaving room for sellers to exploit consumer perception across different quality dimensions. In the high-end dining industry, restaurants can exploit the influcence of their food quality ratings in reputable guidebooks on consumer choice, while neglecting hygiene.

This paper makes a few methodological contributions to the literature. First, our regression model is derived from the optimization problem of a restaurant. This model-based approach provides a microeconomic foundation for the empirical analysis of factors affecting hygiene standards. Second, our estimation method is based on zero-inflated Poisson regression (Lambert 1992). As compared to the linear regression method used in much of the literature (e.g., Jin and Leslie 2009), our method is a useful alternative when analyzing hygiene data, because it accommodates a large number of zero-valued observations, the bunching of observations at integer values, and their rapidly decreasing frequency. Finally, our approach addresses the issue of restricted hygiene data availability. Ideally, a study should get access to the raw hygiene inspection scores (e.g., 0–100 scale in Los Angeles, 0–80 scale in the UK). However, due to data protection regulations and privacy laws, these raw scores are often unavailable. Instead, researchers frequently have access only to coarse hygiene grades available to general public (e.g., 0–5 or A–E grades). We provide a modeling approach deals with such a restricted data environment.

Related Literature. This paper contributes to the literature on food hygiene regulation, and more broadly, to the literature on quality assurance through information disclosure and certification.

A related paper is Jin and Leslie (2009) (henceforth, JL), an empirical study of how reputation-related factors affect restaurants' incentives to provide good hygiene, with the main focus on the reputation for chain-affiliated restaurants (e.g., KFC, Burger King). JL estimate a linear regression using restaurant data from Los Angeles between 1995 and 1998. While JL include Zagat guide ratings of restaurants in the list of the control variables of their model, they do not make any conclusive inference from that, thus leaving the connection between food quality and hygiene effort an open question. Our paper complements JL, by considering data from a different geographic area and different time, and by estimating a flexible, microeconomically founded model. Unlike JL, we obtain conclusive results that relate food quality rating and hygiene.

The food hygiene quality literature, which emphasizes asymmetric product-quality information between restaurants and customers, has its foundations in the literature on verifiable disclosure and certification (for overview, see Dranove and Jin, 2010). Most of the related literature is concerned with the effect of disclosure rules of hygiene grades on incentives to provide good hygiene. Jin and Leslie (2003) show that the enforcement of a mandatory hygiene rating disclosure policy in Los Angeles in 1998 was effective for enhancing hygiene scores and curbing foodborne illness (see also Jin and Leslie 2005). Simon et al. (2005) report the reduction of foodborne illness rates in Los Angeles compared the rest of California, as a consequence of introduction of publicly posted hygiene grade cards. Ho (2012) analyses and compares the mandatory hygiene information disclosure in New York and San Diego. Jin and Lee (2014) study the effectiveness of a new hygiene inspection technology introduced in Florida State. Wong et al. (2015) and Zhu (2016) report detailed investigations regarding the effects of mandatory hygiene card disclosure regulation in New York City. Despite the rapid expansion of the literature over the last two decades, to the best of our knowledge, no study has proposed an estimation framework derived from an optimization problem. Our study fills this gap.

A few papers within this literature tackle other research questions. Based on collected survey data in Ontario, Henson et al. (2006) investigate how consumers perceive restaurant safety issues in practice. Kang et al. (2013) provide an algorithmic approach that extracts information from social media to accurately discover restaurants with poor sanitary conditions. Lehman, Kovács, and Carroll (2014) study consumers' attitude towards restaurants' hygiene and authenticity, and provide empirical evidence that authenticity considerations tend to take precedence. Jin and Lee (2018) examine the effect of repeated hygiene inspections in Florida, and Zhu (2019) further investigates this topic in Seattle. Finally, Bederson et al. (2018) study restaurants' incentives to disclose their food hygiene grades under a voluntary disclosure policy. We add to this literature by reporting new aspects, such as the relation between hygiene scores and the existence of multiple chefs at restaurants.

2. Model

We study a simple and stylized model of restaurant's choice of its hygiene standard. Consider a representative restaurant i. Denote by $Y_i \geq 0$ the incidence rate of foodborne illness, that is, the number of food illness cases in a given interval of time. Since our study is focused on a generally healthy environment, not every restaurant is exposed to bacteria causing gastrointestinal diseases, in which case hygiene conditions do not matter and $Y_i = 0$. However, if the restaurant is exposed to such bacteria, then hygiene conditions do matter, and the incidence rate is assumed to have a Poisson distribution with a mean of λ_i. Denote by $\rho \in (0, 1)$ the probability of exposure to bacteria causing gastrointestinal diseases. Variable Y_i thus has *zero-inflated Poisson* distribution:

$$\Pr(Y_i = y|\lambda_i) = \begin{cases} 1 - \rho + \rho e^{-\lambda_i}, & \text{if } y = 0, \\ \rho \lambda_i^y e^{-\lambda_i}/(y!), & \text{if } y > 0. \end{cases} \tag{1}$$

We now describe how the mean incidence rate λ_i is determined. For convenience, let us introduce the notation

$$h_i = \eta(\ln \underline{\lambda} - \ln \lambda_i),$$

where $\underline{\lambda}$ is a baseline incidence rate and $\eta > 0$ is a scaling parameter. We refer to h_i as *hygiene level*, where a higher h_i means better hygiene standards.

Suppose that restaurant i faces the quantity demanded q_i (the number of customers per a period of time) that depends on price p_i, hygiene level h_i, and a profile of other demand shifting control variables $Z_i = (1, Z_{i1}, ..., Z_{im})$:

$$q_i = \max\{\alpha h_i + Z_i' \bar{\beta} - \mu p_i, 0\},$$

where $\alpha > 0$, $\mu > 0$, and $\bar{\beta} = (\beta_0, \beta_1, ...\beta_m) \in \mathbb{R}^{m+1}$ are parameters. The restaurant's profit is given by

$$\pi_i = \max_{p_i} (p_i - C_i'\bar{\gamma})q_i - \kappa h_i^2 - K_i,$$

where $C_i = (1, C_{i1}, ..., C_{in})$ is a profile of control variables that are components of the variable costs, $\bar{\gamma} = (\gamma_0, \gamma_1, ..., \gamma_n) \in \mathbb{R}^{n+1}$ and $\kappa > 0$ are parameters, and the term $(\kappa h_i^2 + K_i)$ is a fixed cost. So, κh_i^2 represents the part of the fixed cost spent on hygiene, and K_i includes all other fixed costs. We assume that the hygiene cost parameter is not too small, $\kappa > \alpha^2/(4\mu)$, to guarantee existence of a solution.

The profit is maximized by the price p_i chosen to satisfy the first-order condition

$$(\alpha h_i + Z_i'\bar{\beta} - \mu p_i) + (p_i - C_i'\bar{\gamma})(-\mu) = 0.$$

Solving for optimal p_i and substituting the solution into the quantity q_i and the profit π_i yields

$$q_i = \tfrac{1}{2}(\alpha h_i + Z_i'\bar{\beta} - \mu C_i'\bar{\gamma}),$$

and

$$\pi_i = \tfrac{1}{4\mu}\left(\alpha h_i + Z_i'\bar{\beta} - \mu C_i'\bar{\gamma}\right)^2 - \kappa h_i^2 - K_i.$$

The profit function is concave in h_i under our assumption of $\kappa > \alpha^2/(4\mu)$. We find the hygiene level h_i that maximizes the profit, thus satisfying the first-order condition:

$$\frac{\alpha\left(\alpha h_i + Z_i'\bar{\beta} - \mu C_i'\bar{\gamma}\right)}{2\mu} - 2\kappa h_i = 0. \tag{2}$$

Notice that when this condition holds, the quantity demanded must be positive:

$$q_i = \frac{1}{2}(\alpha h_i + Z_i'\bar{\beta} - \mu C_i'\bar{\gamma}) = \frac{2\kappa\mu h_i}{\alpha} > 0,$$

so we do not need to worry about the constraint that $q_i \geq 0$. Substituting $h_i = \eta(\ln \underline{\lambda} - \ln \lambda_i)$ into (2) and solving for $\ln \lambda_i$ yields

$$\ln \lambda_i = \ln \underline{\lambda} + A(Z_i'\bar{\beta} - \mu C_i'\bar{\gamma}), \tag{3}$$

where $A = \alpha/(4\kappa\mu - \alpha^2)$ is a positive constant.

Our model thus connects the mean incidence rate λ_i with demand shifting variables Z_i and cost shifting variables C_i via the first-order condition (3). Observe that the right-hand side of (3) is a linear expression in Z_i and C_i. Equation (3) can be concisely represented by the log-linear expression that relates λ_i and all control variables combined into a single vector[3] $X_i = (1, Z_{i1}, ..., Z_{im}, C_{i1}, ..., C_{in})$,

$$\ln \lambda_i = X_i' \bar{b}, \tag{4}$$

where $\bar{b} = (b_0, b_1, ..., b_{m+n}) \in \mathbb{R}^{m+n+1}$ is the profile of parameters given by

$$b_k = \begin{cases} \ln \underline{\lambda} + (\alpha\beta_0 - \alpha\mu\gamma_0 - 2\kappa\mu)/(\alpha^2\eta) & \text{if } k = 0, \\ \beta_k/(\alpha\eta) & \text{for each } k = 1, ..., m, \\ (-\mu\gamma_{k-m})/(\alpha\eta) & \text{for each } k = m+1, ..., m+n. \end{cases}$$

From (1) and (4), the relationship between the vector of control variables X_i and the output variable Y_i follows a zero-inflated Poisson model (Lambert 1992).

This linear specification of the right-hand side of (4) allows us to include in our estimation a range of demand and cost shifting control variables to capture restaurant-level heterogeneity. In addition to food quality ratings, such variables include: capacity (number of seats), cuisine type, the presence of multiple of chefs, the availability of a wine list, the presence of nearby competitors, and the workload of hygiene inspectors. Furthermore, exploiting the unique nature of the printed guidebooks that the information in their issues remains constant for a substantial period of time, we use the guidebook listed price, as a control variable as it captures consumers' expectations that could be otherwise difficult to observe.

3. Data Description

Our study focuses on the UK high-end restaurant market. We use restaurant-level data from two sources. The hygiene data comes from publicly available hygiene reports from the Food Standards Agency (FSA), the UK regulatory body of food safety and hygiene. The other restaurant-level variables (food quality review score, seat capacity, cuisine, etc.) come from the two most popular periodic restaurant guidebooks in the UK: *The Michelin Guide* and *The Good Food Guide*. We discuss the data in further detail below.

3.1. **Hygiene Rating.**

In practice, the incidence rate of foodborne illness is unobservable for two major reasons. First, gastrointestinal and foodborne diseases are often caused by bacteria with long incubation periods, so tracking the source of a disease is often difficult. Second, a large fraction of non-life threatening cases of

[3] If the same control variable is included into both profiles, Z_i and C_i, then it enters into X_i only once.

Table 1. The FSA 6-tier Food Hygiene Rating Scheme.

Description of Hygiene Rating	Rating (H_i)	$Y_i = 5 - H_i$
Very Good	5	0
Good	4	1
Generally Satisfactory	3	2
Improvement Necessary	2	3
Major Improvement Necessary	1	4
Urgent Improvement Necessary	0	5

infectious intestinal disease and food poisoning remain unreported or undiagnosed properly. So, as a proxy to the unobservable incidence rate, we will use the food hygiene inspection ratings provided by local authorities. Specifically, we use the data from England, Northern Ireland, and Wales-based restaurants from the Food Standards Agency (henceforth, FSA).[4] The FSA introduced its nationwide hygiene inspection criteria in 2008, and since the introduction, it emphasizes and enforces the uniformity, consistency, and comparability of the hygiene evaluation process across the three countries.

In England, Northern Ireland, and Wales, local municipalities are responsible for implementing the FSA regulations and conducting on-site inspections of food-related premises. Municipal officers periodically visit premises and conduct hygiene-related inspections using a grading system from 0 to 80. During an inspection, the officer goes through a checklist of faults and problems in food handling hygiene and safety procedures, structural requirements, and confidence in management, adding points for each violation, up the maximum of 80.[5] The resulting grade is then categorized into a 6-tier rating (0 to 5), with 5 being best and 0 being worst, as shown in Table 1.[6] The 6-tier hygiene ratings are published on the FSA website, where consumers can look them up by searching for the restaurant's name.[7,8]

[4]Scotland has its own regulatory body, Food Standards Scotland, that implements a different, 2-tier ("pass" and "improvement required") hygiene scoring system, which is difficult to compare with that of FSA. We thus exclude Scotland from our study.

[5]E.g., see https://torridge.gov.uk/CHttpHandler.ashx?id=9186&p=0.

[6]From https://www.food.gov.uk/safety-hygiene/food-hygiene-rating-scheme.

[7]See http://ratings.food.gov.uk.

[8]Zapechelnyuk (2019) suggests that the disclosure of grades on a fine scale may be socially undesirable; in fact, even the 6-tier rating scheme is inferior to the 2-tier rating (pass/fail) under a wide range of assumptions.

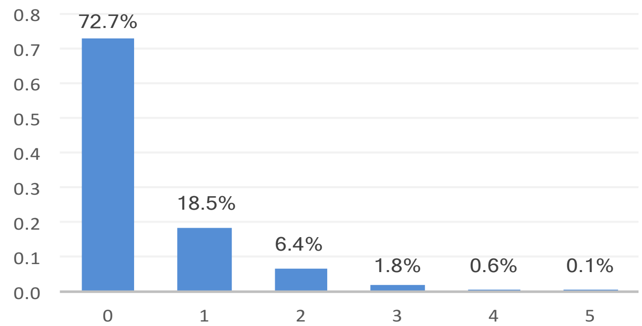


FIGURE 1. Histogram of Hygiene Scores Y_i in the Dataset

In our study, we use the FSA food hygiene rating $H_i \in \{0, 1, 2, 3, 4, 5\}$ as a proxy for the incidence rate. For consistency with the Poisson model, our regressand Y_i is defined as

$$Y_i = 5 - H_i.$$

So, a higher Y_i corresponds to worse hygiene standards (see Table 1).

Since we use the Poisson model, Y_i has the domain of nonnegative integers. Yet, the data restricts Y_i to be between 0 and 5. The theoretically possible values of $Y_i > 5$ correspond to hygiene standards even worse than "Urgent Improvement Necessary" ($Y_i = 5$). So, it is reasonable to assume that such restaurants are required to close down and, thus, are unobservable. We argue that this top censoring is not a major concern. As shown in Figure 1, the frequency of $Y_i = k$ decreases fast as k goes up. In fact, there is a single observation of $Y_i = 5$. So, if there was a possibility to add $Y_i = 6, 7, ...$, the likely effect on the results would be negligible.

3.2. **Food Quality Reviews.** Our primary focus is on the relationship between hygiene standards and food quality reviews. Our restaurant-level food quality scores come from two popular annual restaurant guidebooks in the UK, *the Michelin Guide 2019: Great Britain and Ireland* (henceforth, MG) and *The Good Food Guide 2019* (henceforth, GFG). A notable feature of these guidebooks is their nested content. Nearly all Michelin starred restaurants are included in GFG. Thus, we are able to use the restaurant-level data extracted from GFG, as well as a combined food quality review score that incorporates both the GFG score and Michelin stars (if any).

The MG is a local version of the globally recognized Michelin-brand guidebook series. One of the notable characteristics of this guidebook is its exclusive star-rating system. It lists 'star'-rated restaurants, from one to three stars, according to the criteria

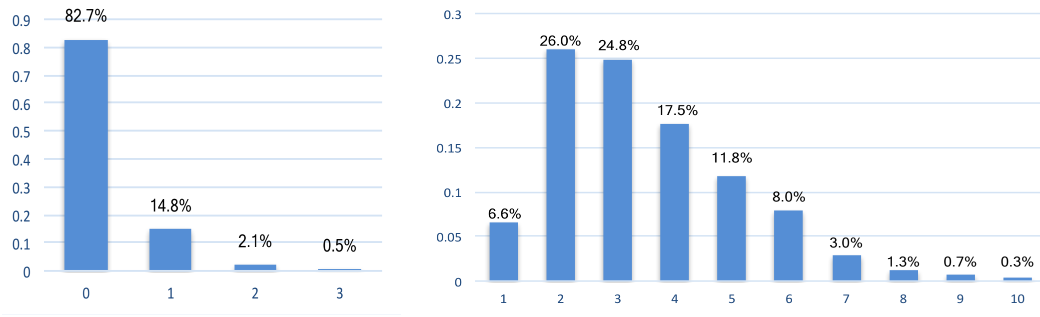
Table 2. Michelin Star Rating

Rating	Description
Three Stars	Exceptional cuisine, worth a special journey
Two Stars	Excellent cooking, worth a detour
One Star	High quality cooking, worth a stop

Table 3. Good Food Guide Scores

Score	Description
10	Perfect dishes showing faultless technique at every service. An extremely rare accolade.
9	Cooking that has reached a pinnacle of achievement. A hugely memorable experience.
8	Highly individual with impressive artistry. There is little room for disappointment here.
7	High level of ambition. Attention to the smallest detail. Accurate and vibrant dishes.
6	Exemplary cooking skills, innovative ideas, impeccable ingredients and an element of excitement.
5	Exact cooking techniques, balance and depth of flavour. A degree of ambition.
4	Dedicated, focused approach to cooking. Good classical skills, high-quality ingredients.
3	Good cooking, showing sound technical skills and using quality ingredients.
2	Decent cooking, good technical skills, interesting combinations and flavours. Occasional inconsistencies.
1	Capable cooking with simple food combinations and clear flavours, but some inconsistencies.

described in Table 2. There are under 200 Michelin starred restaurants in the UK in 2019, and it is widely recognized among restaurant industry participants that obtaining a Michelin star is a prestigious accomplishment for restaurant owners and chefs.



Michelin Stars GFG Scores

Figure 2. Histograms of Michelin Stars and GFG Scores in the Dataset

The GFG is another very popular restaurant guidebook in the UK, which rates about 900 high-end restaurants per year across the UK. For each restaurant, this guidebook reports a score of 10 (maximum) to 1 (minimum), which is awarded by the Good Food Guide editorial office, as well as the typical price of a three-course meal, number of seats, cuisine type, opening days and hours, and other information. Descriptions of GFG scores are provided in Table 3.

Histograms of the MG stars and GFG scores in the data are shown in Figure 2.

In our analysis, we denote a restaurant i's food quality score by F_i. We consider the combined score[9]

$$F_i = 0.5 F_i^{GFG} + 0.5 F_i^{MG},$$

where F_i^{GFG} is the GFG review score in $\{1, ..., 10\}$, and F_i^{MG} is the MG score defined as follows:

$$F_i^{MG} = \frac{10}{3}(\# \text{ of stars}).$$

So, Michelin stars are mapped to the GFG scoring system proportionally: 3 stars corresponds to the GFG score 10, 2 stars to the GFG score 6.7, etc.

With the growth in popularity of consumer review based internet platforms, most notably Tripadvisor, it might be a concern whether the professional review guides actually influence consumer choice. Although we do not have any direct evidence that confirms this, by monitoring Google search queries for MG and GFG vs Tripadvisor, we find that, while Tripadvisor has grown in popularity, the relative interest in the

[9]As a robustness check, we will also estimate the regression with a non-combined GFG score, F_i^{GFG}, instead of the combined score, F_i.

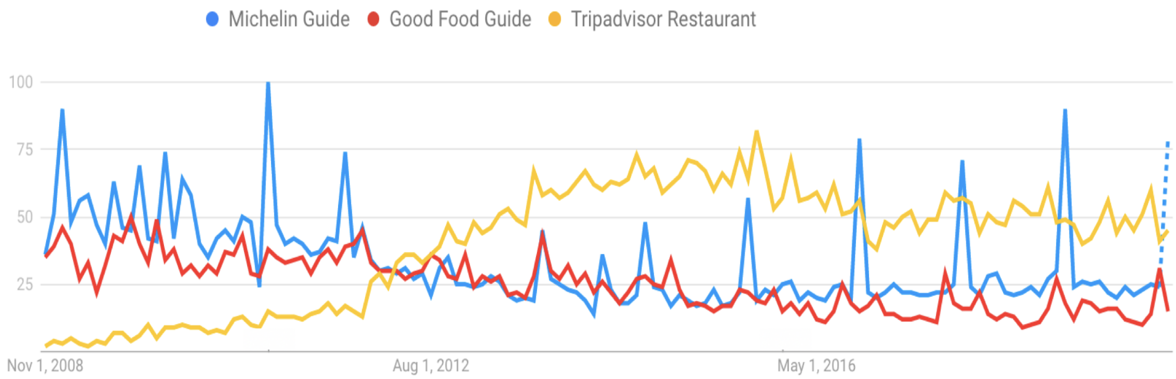


FIGURE 3. This Google Trends figure shows the relative intensity of Google searches for the keywords 'Michelin Guide', 'Good Food Guide', and 'Tripadvisor Restaurant' in the UK from Nov 1, 2008 to Nov 1, 2019.

TABLE 4. Amazon Bestseller Book Ranking (as of December 2018).

Guidebook Name	Amazon.co.uk Bestseller Book Ranking	
	General Category	Restaurants, Bars & Cafés for Travelers
The Michelin Guide: Great Britain and Ireland, 2019	870th	2nd
The Good Food Guide, 2019	1,265th	3rd
Harden's UK Restaurant Survey, 2019	37,102nd	54th
The AA Restaurant Guide, 2019	64,294th	193rd

professional guides has remained steady over time (Figure 3).[10] The spikes of the blue (MG) and red (GFG) lines coincide with the annual publications of new editions each autumn. So, to this day, the interest spikes around new editions of the Michelin guide overshadow the interest in Tripadvisor.

Another possible concern is that the MG and GFG are not the only restaurant guidebooks published for the UK market. There are others, namely Harden's UK Restaurant Survey and the AA Restaurant Guide. These guidebooks, however, are not as popular: the popularity gap between GFG and MG and the other two can be seen

[10]The figure can be reproduced here: https://trends.google.com/trends/explore?cat=71&date=2008-10-15%202019-10-15&geo=GB&q=Michelin%20Guide,Good%20Food%20Guide,Tripadvisor%20Restaurant

from the Amazon bestseller book ranking of these guidebooks from December 2018, soon after the publication of their 2019 issues (Table 4).

3.3. **Hygiene Rating Disclosure.** When the FSA introduced its unified framework of hygiene evaluation in 2008, it was each restaurant's voluntary choice whether or not to display its FSA hygiene rating on the premises. This voluntary disclosure system still continues in England, as of 2019. However, regulatory changes have happened in Wales and Northern Ireland. In response to growing public concerns about food safety and hygiene conditions,[11] the Food Hygiene Rating (Wales) Act 2013 and the Food Hygiene Rating (Northern Ireland) Act 2016 made it mandatory for restaurants to disclose their food hygiene score through a sticker posted on their front door.[12] Following the regulatory changes in Wales and Northern Ireland, there is an ongoing active debate in England on whether regulators should enforce mandatory disclosure. This debate has received high media attention.[13]

We take advantage of this difference in hygiene rating disclosure regulations between Northern Ireland & Wales and England to study whether the mandatory disclosure is related to the hygiene standards decisions. For this purpose, we will include a dummy for Northern Ireland & Wales in the list of control variables.

3.4. **Competition.** To parsimoniously capture the presence of local competition, we include a competition dummy variable CD_i that indicates if there are one or more rival restaurants within 1/4 mile radius. To establish the presence of rivals, we identify each restaurant's geographic location by its postcode (see Figure 4), and then calculate the number of its rivals within 1/4 mile using ArcGIS. This construction of the dummy variable splits the restaurants into two roughly equal groups (48.1% for competitive and 52.9% for non-competitive). Note that our competition dummy accounts only for the restaurants in our GFG dataset. While it would be ideal to take into account all existing restaurants, our proxy for the presence of competition is sensible for

[11]For example, "'Scores on the doors' food hygiene ratings needs more resources, union leader warns" (WalesOnline, Aug 19, 2013): https://www.walesonline.co.uk/news/wales-news/scores-doors-food-hygiene-ratings-5752292.

[12]See https://www.legislation.gov.uk/anaw/2013/2/contents/enacted for Wales 2013 Act, and https://www.legislation.gov.uk/nia/2016/3/contents for Northern Ireland 2016 Act.

[13]For example, "Restaurants and takeaways must display hygiene scores, LGA says" (BBC News, Sep 9, 2017): https://www.bbc.co.uk/news/uk-41203519 and "English businesses 'should be forced to show hygiene scores'" (The Guardian, May 2, 2016): https://www.theguardian.com/business/2016/may/02/english-businesses-should-be-forced-to-show-hygiene-scores

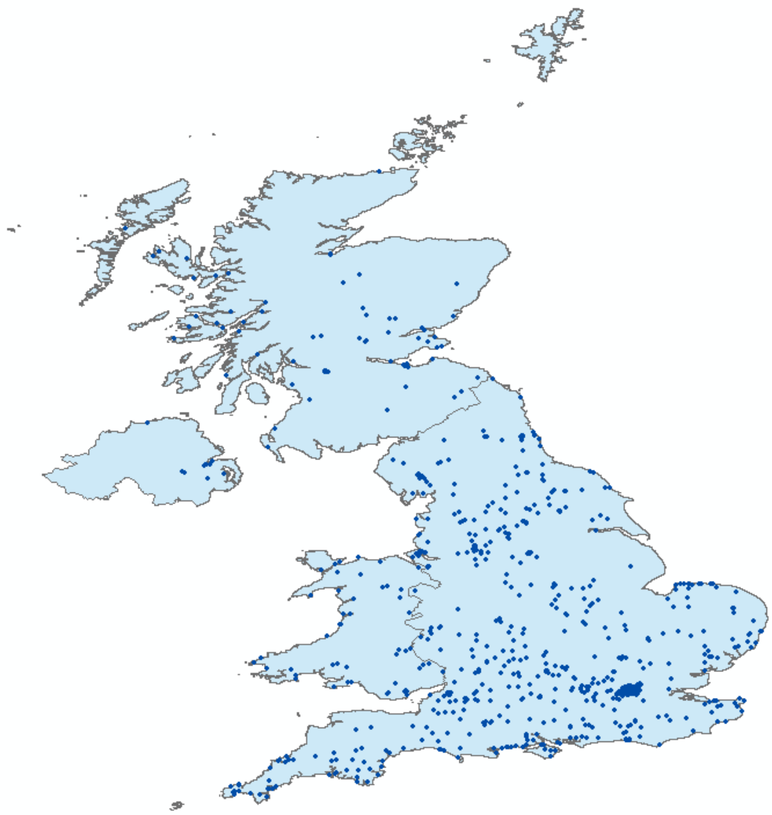


Figure 4. ArcGIS Map of GFG-listed UK Restaurants.

two reasons. First, it is reasonable to assume that the strongest competition effect comes from similar high-end restaurants listed in GFG, rather than with medium and lower-end restaurants. Second, restaurants tend to be either isolated or clustered, e.g., multiple restaurants in town centers and along high streets, and a high proportion of such clusters contains more than one GFG-listed restaurant.

The presence of competition is a demand-shifting factor that has an ambiguous economic effect on hygiene standards. On the one hand, competition increases the marginal return of hygiene standards, thus stimulating the incentive to provide better hygiene. On the other hand, the revenues are competed away, so the cost substitution effect between hygiene and other inputs intensifies. Thus, our particular interest is in the coefficients of the interaction terms between the food quality variable F_i and the competition dummies. These coefficients indicate how the relationship between food quality and hygiene changes when competition is present, as compared to the baseline with no rivals in sight.

3.5. **Workload of Hygiene Inspectors.** Our model takes into account the workload of hygiene inspectors. For that purpose, we include the variable WL_i, a logarithm of the number of food dealing premises per one hygiene inspector in the local authority district where restaurant i is located. This allows us to control for the effect of the variation in the excess or shortage of hygiene inspectors across local authority districts. Similarly to the hygiene rating, the data on the workload of hygiene inspectors comes from FSA.[14]

The workload of hygiene inspectors is a cost-shifting factor that, intuitively, has a negative economic effect on hygiene standards. More overloaded hygiene inspectors are likely to backlog inspections and can be less thorough, so the restaurants can have more incentive to invest into food quality rather than hygiene.

3.6. **Other Control Variables.** We will use a few other restaurant-level control variables obtained from GFG: listed price, seat capacity, cuisine types, the presence of multiple chefs, and the availability of a wine list. We use these variables to parsimoniously capture restaurant-level demand and cost heterogeneity.

The GFG listed price variable X_i^{LG} is the GFG evaluation of the price of a three-course meal in restaurant i. It serves as a price gauge for the consumers, thus affecting the demand. The listed price is fixed in the short run: while the restaurant is free to adjust its prices any time, the GFG listed price is only updated once a year, when an annual GFG publication is out. The capacity variable X_i^Q is the GFG-published number of seats in restaurant i. The capacity is indirectly related to the restaurant's variable cost through the economy of scale. The wine list availability dummy variable X_i^W is added to capture the type of customers' dining experience and overall quality of the establishment. The dummy variable MC_i for the presence of multiple chefs is included as an indication of both scale and the availability of extra hands to take care of multiple tasks, such as hygiene routines. Finally, we control for cuisine types listed in GFG. For this purpose, we add a dummy variable D_i^{cui} for a few popular cuisine types in GFG: $cui \in \{$British, French, Italian, European, Chinese, Indian, Japanese, Seafood, International$\}$, and all other cuisine types are the baseline.

3.7. **Dataset.** The restaurant dataset comprises individual records of all 1116 restaurants in England, Northern Ireland, and Wales that are listed in GFG 2019. Each restaurant's individual data (name, address, number of seats, listed price, cuisine

[14]https://webarchive.nationalarchives.gov.uk/20171207164658/https://www.food.gov.uk/enforcement/monitoring/laems/mondatabyyear.

type, wine list availability, number of chefs, and food quality score) are extracted from GFG 2019. The star rating of Michelin starred restaurants is obtained from MG 2019. Out of the total of 166 Michelin starred restaurants in MG 2019, 155 are also listed in GFG, and thus contained in our dataset. Each restaurant's hygiene rating is obtained from the FSA official website.[15] Each restaurant is matched across the data sources by its name and postal address.

For the estimation, we exclude from the dataset 88 observations that have no FSA hygiene rating (awaiting inspection or closed). We further exclude 26 observations whose GFG score or other variables are missing from GFG (e.g., new chef or awaiting review) and 148 restaurant entries that are assigned a category of *Local Gem* instead of a GFG score (though the *Local Gems* are later reintroduced to the dataset as a robustness check). After these exclusions, the sample size is 854.

4. Estimation Results

Based on the zero-inflated Poisson model (1) and the mean specification (4), we apply the pseudo-maximum likelihood estimation method, which is robust to model misspecifications. The regressand is the hygiene score Y_i (see Section 3.1), and Poisson mean λ_i of each restaurant i is specified as

$$\begin{aligned}\ln \lambda_i = b_0 + b_F F_i + b_{NIW} NIW_i + b_{CD} CD_i + b_{MC} MC_i \\ + \sum\nolimits_{cui} b_{cui} D_i^{cui} + \sum\nolimits_{con} b_{con} X_i^{con}.\end{aligned} \tag{5}$$

In the above specification:

- F_i is the food quality score (see Section 3.2);
- NIW_i is the dummy for Northern Ireland and Wales (see Section 3.3);
- CD_i is the competition dummy for one or more rivals within a 1/4 mile radius (see Section 3.4);
- MC_i is the dummy for the presence of multiple chefs (see Section 3.6);
- D_i^{cui} are the cuisine dummies, $cui \in$ {British, French, Italian, European, Chinese, Indian, Japanese, Seafood, International} (see Section 3.6);
- X_i^{con} are other control variables: the hygiene inspectors workload (see Section 3.5), the GFG listed price, the restaurant capacity, and the dummy of the availability of a wine list (see Section 3.6).

[15] See https://ratings.food.gov.uk.

TABLE 5. Main Regression Results

Dependent Variable: Y_i	Model (5)	Model (6)
Incidence Rate		
Food Quality	.3216** (.1303)	.4883*** (.1500)
Food Quality × NI&Wales	No	-.3434** (.1754)
Food Quality × Competition	No	-.2178 (.1852)
Food Quality × Multiple Chefs	No	-.6358*** (.1932)
Zero Inflation		
Food Quality	.9636 (.6513)	1.574** (.8031)
Food Quality × NI&Wales	No	-2.131*** (.6932)
Food Quality × Competition	No	-.7491 (.4656)
Food Quality × Multiple Chefs	No	-2.637* (1.568)
Other Controls		
Local Variables	Yes	Yes
Restaurant Characteristics	Yes	Yes
Cuisine Categories	Yes	Yes
Log Pseudolikelihood	-652.1087	-640.4056
Wald χ^2 ($Prob > \chi^2$)	37.64 (0.0017)	74.82 (0.0000)
Vuong Test p-value: Zero Inflation	0.0000	0.0000

Notes: *** p≤0.01, ** p≤0.05, * p≤0.1. Robust standard errors in parentheses. Inflation model= *logit*. Local variables include: *NI&Wales dummy*, *competition dummy*, *hygiene inspectors workload*. Restaurant characteristics include: *listed price*, *seat capacity*, *multiple chefs dummy*, *wine list dummy*. Cuisine categories include: *British, French, Italian, European, Chinese, Indian, Japanese, Seafood, International.*

We also estimate another specification where we include the interaction terms between food quality F_i and the dummy variables NIW_i, CD_i, and MC_i:

$$\begin{aligned}\ln\lambda_i &= b_0 + b_F F_i + b_{NIW} NIW_i + b_{CD} CD_i + b_{MC} MC_i \\ &\quad + b_{FNIW}(F_i \cdot NIW_i) + b_{FCD}(F_i \cdot CD_i) + b_{FMC}(F_i \cdot MC_i) \\ &\quad + \sum\nolimits_{cui} b_{cui} D_i^{cui} + \sum\nolimits_{con} b_{con} X_i^{con}.\end{aligned} \tag{6}$$

Table 5 reports the estimation results. The section *Incidence Rate* displays the estimated coefficients in equations (5) and (6) that represent the first-order conditions for profit maximization. This section explains the relationship between the differentiation in the foodborne illness incidence rate and the control variables of the regression, after controlling for excess zeros. The section *Zero Inflation* displays the estimated logit coefficients for the variable predicting excess zeros in the hygiene score data. Within our model interpretation, the coefficients in this section relate the control variables to the probability that a restaurant is not exposed to bacteria causing gastrointestinal diseases. Thus, the positive zero-inflation coefficient 1.574 for food quality F_i in Model (6), which is statistically significant at 5%, indicates that restaurants with higher food quality are less likely to be exposed to foodborne diseases. However, because our focus is on the differentiation of the incidence rates conditional on the exposure to foodborne diseases — the case where hygiene matters — our primary interest is in the coefficients presented in *Incidence Rate* section.

From *Incidence Rate* section, we can see that the food quality score coefficient $\hat{b}_F = 0.3216$ in Model (5) is positive and statistically significant at 5%. While Poisson regression coefficients do not have a clear quantitative interpretation, qualitatively it means that higher food quality review scores are associated with a higher incidence rate of foodborne illness, that is, lower hygiene standards. Moreover, this result is even stronger (significant at 1%) in Model (6), where we further decompose the analysis of the relation between food quality and hygiene by estimating the interaction coefficients with three dummy variables: NI&Wales, competition, and multiple chef dummies.

To explain the economic reason behind the anticorrelation of food quality and hygiene, observe that in a restaurant's profit-maximization problem, a greater food quality score F_i leads to a smaller rate of return of hygiene standards on revenues. In other words, food quality and hygiene are substitutable inputs. Consequently, when restaurants invest more in food quality, they tend to invest less in hygiene. A restaurant's ambition to be included in a prestigious guidebook thus comes at the expense of hygiene, as its effort is being redirected away from maintaining high hygiene standards.

An important element of the above argument is that food quality and hygiene efforts are separately evaluated inputs, assessed by the independent organizations with uncoordinated visit timings. In other words, professional food quality reviewers may not take hygiene standards into account. Indeed, the definitions of Michelin stars (Table 2) and GFG scores (Table 3) focus on the description of food quality. Neither of these guidebooks explicitly includes hygiene conditions in their star/score definitions.

Alternatively, professional food quality reviewers could pay attention to hygiene conditions, but once included in the guidebook, restaurants rest on their laurels until the next round of food quality reviews. Since the food quality reviews and food hygiene inspections are not synchronized, the unlucky timing of a hygiene inspection can result in a low hygiene rating.

Observe that in Model (6), the coefficients at the interaction terms between food quality and two out of three dummy variables, NI&Wales, and multiple chefs dummies, are negative and statistically significant. We now discuss these findings, which can be relevant for hygiene inspection policies and regulations.

As we described in Section 3.3, in Northern Ireland and Wales there is a policy of mandatory disclosure of hygiene ratings to consumers through a front door sticker. Economically this means that the marginal return of food quality on revenues is smaller when the front door sticker shows poor hygiene grades, thus reducing the substitution effect between food quality and hygiene. The reduction of the anticorrelation of food quality and hygiene, captured by the coefficient $\hat{b}_{FNIW} = -0.3434$, is statistically significant at 5%. Furthermore, $\hat{b}_F + \hat{b}_{FNIW} = 0.4883 - 0.3434 = 0.1449$, and the test of $b_F + b_{FNIW} = 0$ comes with the p-value of 0.4510. This result could suggest that the anticorrelation can be mitigated, or even completely negated, by implementation of the mandatory disclosure policy.

Finally, restaurants with multiple chefs also exhibit a smaller effect of anticorrelation between food quality and hygiene. Intuitively, when there are multiple chefs, it is less costly to maintain high hygiene standards. Similarly to the case of competition, this gives stronger incentives to push the hygiene rating to its maximum. Once again, we see the mitigation of the substitution effect between food quality and hygiene. The reduction of the anticorrelation of food quality and hygiene, captured by the coefficient $\hat{b}_{FMC} = -0.6358$, is statistically significant at 1%. Furthermore, $\hat{b}_F + \hat{b}_{FMC} = 0.4883 - 0.6358 = -0.1475$, and the test of $b_F + b_{FMC} = 0$ comes with the p-value of 0.5378, indicating that the presence of multiple chefs could cancel out the anticorrelation. To the best of our knowledge, this multiple chef channel has not been reported in the literature.

Overall, these findings illuminate potential channels through which the anticorrelation between food quality and hygiene could be mitigated, which can be helpful for hygiene inspection design.

Table 6. Robustness Regression Results

Dependent Variable: Y_i	ZINB	Local Gems	Original GFG Score
Incidence Rate			
Food Quality	.4571** (.2194)	.4501*** (.1132)	.4380*** (.1051)
Food Quality × NI&Wales	-.2918 (.3151)	-.3234* (.1777)	-.1738 (.1447)
Food Quality × Competition	-.2012 (.2370)	-.2293 (.1760)	-.2290* (.1169)
Food Quality × Multiple Chefs	-.6139*** (.2383)	No	-.3546*** (.1311)
Zero Inflation			
Food Quality	1.926 (1.645)	1.367*** (.4135)	3.701 (2.706)
Food Quality × NI&Wales	-2.346** (.9243)	-2.202*** (.5468)	-3.385 (2.302)
Food Quality × Competition	-.8909 (.7076)	-.6957* (.4062)	-2.498 (1.737)
Food Quality × Multiple Chefs	-3.265 (2.637)	No	-2.361 (2.080)
Other Controls			
Local Variables	Yes	Yes	Yes
Restaurant Characteristics	Yes	Yes	Yes
Cuisine Categories	Yes	Yes	Yes
Log Pseudolikelihood	-640.1726	-802.0588	-635.5357
Wald χ^2 $(Prob > \chi^2)$	62.54 (0.0000)	63.34 (0.0022)	88.24 (0.0000)
Vuong Test p-value: Zero Inflation	0.0000	0.0000	0.0000
LR Test p-value: $\alpha = 0$	0.4949		

Notes: *** p≤0.01, ** p≤0.05, * p≤0.1. Robust standard errors in parentheses.
Inflation model= *logit*. Local variables include: *NI&Wales dummy*, *competition dummy*, *hygiene inspectors workload*. Restaurant characteristics include: *listed price*, *seat capacity* (except in Local Gems), *multiple chefs dummy* (except in Local Gems), *wine list dummy*.
Cuisine categories include: *British, French, Italian, European, Chinese, Indian, Japanese, Seafood, International.*

5. Robustness

In this section, to check the robustness of our findings, we discuss some variations in estimation methods and the definitions of our variables. We consider Model (6) as the baseline model.

5.1. **Zero-Inflated Negative Binomial Regression.** In our main ZIP model with the Poisson mean given by (6), the only source of error is due to Y_i being a random variable with a zero-inflated Poisson distribution. This model does not account for a possible restaurant-level heterogeneity in estimating the Poisson mean. To correct this deficiency, we estimate a *zero-inflated negative binomial* (ZINB) regression. Let a Poisson mean λ_i be given by

$$\ln \lambda_i = X_i' \bar{b} + \alpha \varepsilon_i, \tag{7}$$

where X_i is the profile of the same control variables as in (5), ε_i is the heterogeneity term that summarizes any factors that are not accounted for in X_i, and α is a parameter. Assume that the exponent of the heterogeneity term, $e^{\alpha \varepsilon_i}$, is Gamma-distributed, and thus $\lambda_i = e^{X_i' \bar{b} + \alpha \varepsilon_i}$ is Gamma-distributed conditional on X_i.

In this model, Y_i is ZIP distributed as defined by (1), with the Gamma-distributed mean λ_i given by (7). That is, the distribution of Y_i is a Gamma-mixture of ZIP distributions, and thus it is a *zero-inflated negative binomial* (ZINB) distribution (e.g., Cameron and Trivedi 2013). Note that, as compared to ZIP, ZINB has one more parameter and usually has a better fit to the data. When this parameter is zero ($\alpha = 0$), the two regression models coincide, in which case ZIP is statistically preferable as it has more degrees of freedom.

The second column in Table 6 reports the results of the ZINB regression. The food quality coefficient, $\hat{b}_F = 0.4571$, has the same sign and magnitude as in ZIP model (6), and is significant at 5%. Overall the estimated coefficients have the same signs and very similar magnitudes. Furthermore, the likelihood ratio test shows that the hypothesis of $\alpha = 0$ is not rejected at any conventional levels of significance. This indicates that our main finding is robust to unobserved heterogeneity, at least in (but not limited to) the mixture distribution sense.

5.2. **Inclusion of Local Gem Restaurants.** The restaurant data extracted from GFG contains 148 observations of restaurants that GFG tagged *Local Gem* instead of assigning them a 10-point score. Because of the absence of GFG scores, the Local Gem restaurants were excluded from the main regression. We now estimate the same regression model (6), but with these restaurants included and assigned a score on the 10-point scale. GFG's description of Local Gems is: "These simple cafés, bistros and pubs are among the best neighbourhood eateries in the country." We use this description within the context of GFG score descriptors (Table 3), as well as the fact that the proportion of Local Gems in the dataset, 13.7%, is similar to that of the restaurants with score 5, 11.8%, to assign each Local Gem the score of $F_i^{GFG} = 5$. We then add these 148 entries to obtain a dataset with 1002 observations in total.

In addition to the absent GFG 10-point score, *Local Gems* have no data about their capacity (the number of seats) or the number of chefs. We thus omit the capacity variable X_i^Q and the multiple chefs dummy MC_i from (6). Because these variables are now omitted, we add another 13 observations that have been previously excluded because of missing capacity or multiple chefs variables. Thus, the dataset now contains 1015 observations.

Column 3 in Table 6 reports the results of the ZIP regression with Local Gems included. Our coefficient of interest, $\hat{b}_F = 0.4501$, has the same sign and similar magnitude to that in ZIP model (6), and is significant at 1%. Overall the estimated coefficients have the same signs and similar magnitudes.

5.3. **Variation of the Food Quality Score.** To check the robustness of our result with respect to our choice of the combined food quality score $F_i = 0.5F_i^{GFG} + 0.5F_i^{MG}$, we estimate a variation of our ZIP regression (6), by replacing the combined score F_i with the GFG score F_i^{GFG}.

Column 4 in Table 6 reports the results of this regression. Once again, the coefficient of the food quality score, $\hat{b}_{F^{GFG}} = 0.4380$, has the same sign and similar magnitude to that in ZIP model (6), and is significant at 1%. Overall the estimated coefficients have the same signs and similar magnitudes, though the coefficient $\hat{b}_{FNIW} = -0.1738$ of the interaction term between food quality and NI&Wales dummy is not significant in this specification. On the other hand, steadily consistent with the previous regressions, $\hat{b}_{FMC} = -0.3546$ is significant at 1% significance level.

In summary, the anticorrelation between hygiene and food quality remains robustly significant across these additional specifications.

6. Conclusion

In this paper, we present a microeconomic model, which can be flexibly used for future food hygiene regression studies. Then, using data from the UK, we show that there is a statistically significant negative conditional correlation between food quality rating provided by popular guidebooks and food hygiene in restaurants. This result is in line with the economic intuition of the substitution effect between restaurant owners' efforts directed to food quality and hygiene. However, this result is often perceived as counterintuitive, as consumers usually expect professional reviewers to judge not only the food quality, but also to cleanliness of the kitchen and adherence of the personnel to food hygiene rules and procedures. Our result suggests that the inclusion of restaurants in prestigious guidebooks appears to be misaligned with the incentives to maintain high hygiene standards, which raises concerns about consumer protection and public health. In addition, potentially appealing to hygiene regulators and policymakers, our study also finds that some economic factors, such as mandatory disclosure regulations and existence of multiple chefs, could offset the anticorrelation. This finding could be informative for designing hygiene inspection policies.

Our estimation method makes use of the zero-inflated Poisson regression and is model-based. Our result is robust to a few alternative model specifications. The main deficiency of the analysis is a relatively small dataset and unavailability of panel data that keeps track of the same set of restaurants over a period of time. An analysis with an expanded dataset, both in scope and time, is left for future research.

References

Bederson, B. B., G. Z. Jin, P. Leslie, A. J. Quinn, and B. Zou (2018): "Incomplete Disclosure: Evidence of Signaling and Countersignaling," *American Economic Journal: Microeconomics*, 10, 41–66.

Cameron, A. C., and P. K. Trivedi (2013): *Regression Analysis of Count Data*. Cambridge University Press, 2nd edn.

Dranove, D., and G. Z. Jin (2010): "Quality Disclosure and Certification: Theory and Practice," *Journal of Economic Literature*, 48, 935–63.

Henson, S., S. Majowicz, O. Masakure, P. Sockett, A. Jones, R. Hart, D. Carr, and L. Knowles (2006): "Consumer Assessment of the Safety of Restaurants: The Role of Inspection Notices and Other Information Cues," *Journal of Food Safety*, 26, 275–301.

Ho, D. E. (2012): "Fudging the Nudge: Information Disclosure and Restaurant Grading," *Yale Law Journal*, 122, 574–689.

Jin, G. Z., and J. Lee (2014): "Inspection Technology, Detection, and Compliance: Evidence from Florida Restaurant Inspections," *RAND Journal of Economics*, 45, 885–917.

——— (2018): "A Tale of Repetition: Lessons from Florida Restaurant Inspections," *The Journal of Law and Economics*, 61, 159–188.

Jin, G. Z., and P. Leslie (2003): "The Effect of Information on Product Quality: Evidence from Restaurant Hygiene Grade Cards," *Quarterly Journal of Economics*, 118, 409–451.

——— (2005): "The Case in Support of Restaurant Hygiene Grade Cards," *Choices*, 20, 97–102.

——— (2009): "Reputational Incentives for Restaurant Hygiene," *American Economic Journal: Microeconomics*, 1, 237–267.

Kang, J. S., P. Kuznetsova, M. Luca, and Y. Choi (2013): "Where Not to Eat? Improving Public Policy by Predicting Hygiene Inspections Using Online Reviews," in *Proceedings of the 2013 Conference on Empirical Methods in Natural Language Processing*, pp. 1443–1448.

Lambert, D. (1992): "Zero-Inflated Poisson Regression, with an Application to Defects in Manufacturing," *Technometrics*, 34, 1–14.

Lehman, D. W., B. Kovács, and G. R. Carroll (2014): "Conflicting Social Codes and Organizations: Hygiene and Authenticity in Consumer Evaluations of Restaurants," *Management Science*, 60, 2602–2617.

Simon, P. A., P. Leslie, G. Run, G. Z. Jin, R. Reporter, A. Aguirre, and J. E. Fielding (2005): "Impact of Restaurant Hygiene Grade Cards on Foodborne-Disease Hospitalizations in Los Angeles County," *Journal of Environmental Health*, 67, 32–36.

Wong, M. R., W. McKelvey, K. Ito, C. Schiff, J. B. Jacobson, and D. Kass (2015): "Impact of a Letter-Grade Program on Restaurant Sanitary Conditions and Diner Behavior in New York City," *American Journal of Public Health*, 105, e81–e87.

Zapechelnyuk, A. (2019): "Optimal Quality Certification," *American Economic Review: Insights*, forthcoming.

Zhu, J. (2016): "Earning the Grade or Just Window Dressing? The Effects of Information Disclosure on Restaurant Hygiene Quality," mimeo.

——— (2019): "Inspection in Disguise: A Study of Repeated Restaurant Inspections," mimeo.