The cost of food crime

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Executive summary

We were asked to conduct a comprehensive review of existing methods and techniques for evaluating the economic impact of food crime to the UK economy and to develop a conceptual framework based on these findings. This framework captures the full range of impacts that food crime has on the UK economy, and assesses the availability of data needed to provide an estimated cost.

We have developed an economic framework for estimating the economic cost of food crime which uses:

1. Victim costs: Direct economic losses suffered by crime victims, including medical care costs and lost earnings.
2. Criminal justice system costs: Costs of anti-food crime activities, legal and adjudication services, and corrections programs including incarceration.
3. Crime career costs: Opportunity costs associated with the criminal's choice to engage in illegal rather than legal and productive activities.
4. Intangible costs: Indirect losses suffered by crime victims, including pain and suffering, decreased quality of life, and psychological distress.
5. Market costs: Loss of profits[1] for genuine firms.

As well as the framework, we provide a table of data sources which can be used for the quantification of the above costs (Appendix A) and a detailed evaluation of how these sources can be used (see section 3). Finally, an assessment of the possibility of applying machine learning or other tools to build algorithms to calculate the costs is provided in section 4.

This piece of work (Phase 1) constitutes the 'exploratory' phase; aimed at mapping out the drivers and impacts of food crime and establishing a conceptual framework. Phase 2, to be commissioned, would seek to use the outputs of Phase 1 to construct and populate a model, which would necessarily provide working estimates of the impacts of food crime to the UK economy. The Phase 2 steps needed following the development of

[1] Profits in this model are always profits before taxes. The total amount of money or resources available to society as a whole is unaffected by the payment of taxes.

the Phase 1 framework presented in this report are to (a) source the data required based on Appendix A of this report, including negotiations to use databases that are run on a commercial basis; (b) refine and test the model provided here; (c) develop a specification for a database, including the use of machine learning to extract and organise data sourced from external sources. This would involve creating new datasets where indicated in Appendix A of this report; (d) build and test a prototype of the database; and (e) develop and test functions and algorithms to calculate the figures required automatically.

1. Introduction

1.1. Evidence Brief

The scope of this project is to conduct a comprehensive review of existing methods and techniques for evaluating the economic impact of food crime to the UK economy and to develop a conceptual framework based on these findings. This framework will seek to capture the full range of impacts that food crime has on the UK economy, and will be explicit in the areas where data availability prevents estimation. The team has expertise in food crime and forensic accounting, economics of crime, economic impact assessment and data analytics. Our framework will draw on each of these areas to provide a robust methodology for future assessment of the cost of food crime.

The most significant problem in assessing the cost of food crime is the lack of statistical and other evidence, and the consistency of the data that does exist. These are significant challenges which the OECD and others have encountered for decades when trying to assess costs of crime. Therefore, within the scope of the project, we will identify the data sources available and evaluate the extent to which they could be utilised within the framework created to assess the cost of food crime.

1.2. Our approach

First, we carried out a literature review of the growing academic literature on food crime, food fraud, EMA and food defence. We also reviewed reports, articles and presentations produced by food industry, accounting, insurance and consultancy firms for evidence of numbers that had been placed on the cost of food crime. Only two academic papers (Spinks and Fejes, 2012; Lord et al, 2017) assess the cost-benefits of food crime, at the micro-level of an individual item or incident, in order to illustrate that there is an economic motivation for individual entities to engage in food crime.

From media, professional and industry sources, there are only three figures proposed and the same three figures are used regularly to indicate the likely costs involved in EMA or Food Fraud. The rationale and evidence behind these figures are critically evaluated in the Literature Review section. In brief, the generally accepted figures are:

a. The Grocery Manufacturers Association (GMA, 2010) suggested that the total cost of food fraud to the global food and drink industry is US$10-15billion a year.

This is based on surveys of food industry companies who estimated their losses per event and then estimated the number of events.

b. Attributed to PwC (2013), the figure of US$30-40billion for global losses to food fraud is used based on the percentage of product fraud that occurs globally, estimated at 5-7% of World trade (CIB, 1997).
c. The Centre for Counter Fraud Studies at University of Portsmouth gives £11.97bn for the possible losses to the UK, based on loss estimate exercises across organisations in all sectors that show an average fraud loss of 5.92% of turnover per year.

Each of these three figures is a projection rather than derived from a detail economic or accounting methodology and the weaknesses are analysed in Section 2.

In order to complete the evaluation of the generally accepted figures, we also assessed the literature on product crime such as counterfeiting for suitable methodologies. However, no further approaches are acceptable for use in this context.

Second, a review of the literature in economics was undertaken. This covered the literature on the evaluation of economic crimes, from which we are able, in Section 2.3, to identify one suitable approach for the assessment of the economic and social impact of food crime (McCollister et al, 2010).

The next step in our approach was to build on McCollister et al (2010) and create a framework for quantifying the cost of food crime. In brief, our framework for estimating the economic cost of food crime uses:

1. Victim costs: Direct economic losses suffered by crime victims, including medical care costs and lost earnings.
2. Criminal justice system costs: Costs of anti-food crime activities, legal and adjudication services, and corrections programs including incarceration.
3. Crime career costs: Opportunity costs associated with the criminal's choice to engage in illegal rather than legal and productive activities.
4. Intangible costs: Indirect losses suffered by crime victims, including pain and suffering, decreased quality of life, and psychological distress.
5. Market costs: Loss of profits for genuine firms.

From there, it was possible to create a table of data sources and evaluate their possible uses. Finally, an assessment of the possibility of applying machine learning or other tools to build algorithms to calculate the costs is included.

1.3. Definitions of Food Crime

The most significant issue in current estimates of the impact of food crime is that there is confusion between the terms in use. One of the aims of this report is to bring clarity to the issues involved by providing a framework based on the FSA/Elliot (2014) definition of food crime and to isolate the elements that should and should not be included in the calculation of the cost of food crime.

We use the definition of food crime given by the Food Standards Agency (FSA) in the brief for this project, which is stated as:

Consumers should have confidence that their food is safe and what it says it is.

Food crime is serious fraud and related criminality within food supply chains that impacts the safety or the authenticity of food, drink or animal feed. It can be seriously harmful to consumers, food businesses and the wider food industry.[2]

The National Food Crime Unit (NCFU, 2020) itemises food crime as:

- **theft** - dishonestly obtaining food, drink or feed products to profit from their use or sale
- **illegal processing** - slaughtering or preparing meat and related products in unapproved premises or using unauthorised techniques
- **waste diversion** - illegally diverting food, drink or feed meant for disposal, back into the supply chain
- **adulteration** - including a foreign substance which is not on the product's label to lower costs or fake a higher quality
- **substitution** - replacing a food or ingredient with another substance that is similar but inferior

[2] Food crime (original quote extended following advice from the NFCU)

- **misrepresentation** - marketing or labelling a product to wrongly portray its quality, safety, origin or freshness
- **document fraud** - making, using or possessing false documents with the intent to sell or market a fraudulent or substandard product

These definitions are a refinement of those given in Elliot (2014) following the 2013 Horsemeat Scandal in Europe (the NFCU was set up following recommendations in this report), which stated that:

Food fraud encompasses deliberate and intentional substitution, addition, tampering, or misrepresentation of food, food ingredients, or food packaging; or false or misleading statements made about a product for economic gain. The types of fraud include adulteration, tampering, product overrun, theft, diversion, simulation, and counterfeiting. Food fraud becomes food crime when it no longer involves random acts by 'rogues' within the food industry but becomes an organised activity perpetrated by groups who knowingly set out to deceive, and or injure, those purchasing a food product

The current FSA/NFCU definitions recognise the serious nature of food crime but clarify that the crimes include fraud (which is a crime under the 2006 Fraud Act) and lose the implication that the crime aspect is only the result of organised criminal groups. In other words, we depart from the Elliot (2014) definition and treat all the items listed by the FSA as food crime, of which food fraud is a sub-group.

There are other terms in use that overlap with these definitions. It is important to understand the differences between the terms used, in order to be precise about what we are measuring when we attempt to measure the cost of food crime.

In the USA, the term Economically Motivated Adulteration (EMA) is specific sub-group of food fraud and emphasises the economic gain that needs to be present for the incident to be recognised as food fraud. The alternative is that the food product was tampered with maliciously, with an intent to injure. Unlike the definition in Elliot (2014), most researchers treat the intent to injure as a separate issue under the heading 'Food Defence'. This recognises that those engaged in EMA rarely set out to injure people, as although this may happen as a consequence of their actions, this would negate the longer-term economic gain to be had from the continuation of the fraud. Moyer and Spink (2011, R157) clarified this usage by stating that:

Food fraud, including the more defined subcategory of economically motivated adulteration, is a food risk that is gaining recognition and concern. …. Food safety, food fraud, and food defense incidents can create adulteration of food with public health threats. Food fraud is an intentional act for economic gain, whereas a food safety incident is an unintentional act with unintentional harm, and a food defence incident is an intentional act with intentional harm.

In our framework, we do treat all food crime as listed by the NFCU (as quoted above) as serious fraud and related criminality within food supply chains that has an impact on the safety or the authenticity of food, drink or animal feed. To restate the NFCU position, this comprises theft, unlawful processing, waste diversion, adulteration, substitution and counterfeiting, misrepresentation and document fraud. From this, we can see that the victims are consumers, food businesses[3] and the wider food industry. This enables us to build a framework based on the crime aspect of the issue that has health and economic impacts, rather than as a primarily technical food safety issue.

2. Literature Review

No one study has yet found a way of estimating the economic cost of what is an economic crime. In this literature review, we look first at the extent to which current studies of food crime identify the costs and impacts and then evaluate in more depth the only three calculations in circulation for the cost of food fraud. We conclude that current calculations are flawed because they are based on broad assumptions and proxy data. We then review the literature on the economic analysis of crime and the measurement of economic impact on society.

2.1 A review of the general literature on food crime and related terms

The academic literature on food fraud identifies but does not quantify the costs of food fraud. These are essentially the costs of hospitalisation or fatality from unintentional

[3] We recognise that 96% of the UK food businesses are small and medium sized enterprises, accounting for 25% of the national turnover in food sales in the UK (DEFRA, 2020). However, this version of the model looks on the impact of food crime as a whole rather than relative impacts on different businesses or individuals.

contamination of fraudulent food items and the costs of reputational damage or insolvency from incidents. These might be classed as catastrophic. There are also long term and more qualitative issues of long-term impairment of health through poor nutrition; loss in confidence in the food industry; loss of taxation and duties through related frauds; and effects of unfair competition on business growth. (see, for example, Manning and Soon, 2016; Johnson, 2014).

Very few studies examine the issue from the point of view of the criminal and the economic impact of their behaviour, or alternatively, through the point of view of the consumer as a victim. As NSF/FSA (2015) show, food fraud is likely to occur at a conjunction of profit, likelihood of detection and ease of perpetration. In practice, there are very few, if any, foods that are not liable to some form of mis-labelling, substitution, adulteration, counterfeiting or illegal processing. The majority of frauds are likely to be of low margin, high volume items with smaller number of high margin, low volume items (NSF, 2015; Gee, Button and Daly, 2017). As the majority of food and drink businesses run on very tight net margins, the temptation to engage in food fraud, for example, is high (NSF, 2015; Lord et al, 2017b). Furthermore, many food crimes concern violations other than the manipulation of the food or drink, such as customs duty or tax evasion, smuggling, false accounting or embezzlement. These are included in the FSA definition we are using under the heading ‘document fraud’ (NFCU, 2020) while the GFSI include them under ‘false and misleading statements’ (GFSI, 2018).

Recently, Spink, DeVriejs and Moyer (2017) have assessed potential economic gains for those committing food fraud based on the costs of substituted ingredients and additional processing. For example, they conduct an ingredient level analysis of protein bars, with melamine substituting for wheat gluten. This would net 13 cents per bar for the fraudster: if 10 truckloads of the energy bar were produced, the economic gain from the fraud would be US$62,000 (Ibid). The study demonstrates the economic gains available on even small-scale acts of mis-labelling, substitution, adulteration and counterfeiting by individuals but does not easily aggregate into an economic-societal cost of the impact of food fraud.

A further approach is to look at the willingness to pay (WTP) by consumers for fraud protection measures (for example, Stickle, 2015 on WTP for burglary prevention or

Brenig and Proeger 2018 on WTP for crime reduction). The FSA (2017) has investigated WTP and Quality Adjusted Life Years (QALY) in relation to food borne illnesses from food safety incidents. The data for these calculations is based on survey data of the UK population, asking questions in relation to 10 common and serious food borne illnesses. In aggregate, the impact (burden to the government) of food borne illness is assessed as £936million a year. The main difficulty in the case of using similar approaches to assess the cost of food fraud is that relatively few frauds result in illness, which is against the interests of the perpetrator (NSF, 2015). We make use of the monetary willingness to pay value for quality adjusted life years within the proposed framework sections that are specifically related to the end consumers of food.

As food crime has attracted more attention over the last decade, there have been responses to help the industry identify and protect themselves. These include the development of more sophisticated scientific testing methods; the development of fraud risk and vulnerability analysis models such as Vulnerability Analysis and Critical Control Points (VACCP); horizon scanning using Internet and media data; human intelligence; self-reporting systems for organisations and counter fraud models (Soon, Krzyzaniak, Shuttlewood, Smith and Jack, 2019; Manning and Soon, 2016). The literature on food crime is largely concerned with documenting state of play and definitions (see, for example, Manning and Soon, 2016). There is some work on victims and the consequences of food crime (Spink, Ortega, Chen and Wu, 2017), but no clear analysis of the economic consequences of the different types of food crime, as set out in the specification document for this project. One weakness is that the literature and the risk assessment techniques concentrate on individual food items rather than looking at the different crimes that could take place and their potential outcomes.

2.2 Previous estimates of the cost of food crime

We carried out a comprehensive Internet search to identify which figures are used in the media, professional and industry sources and identified the only three figures that are used to indicate the extent of food fraud and EMA. The FSA has used these figures, which estimate the cost food fraud to the industry be around US$10-15bn in the USA, £11.6bn in the UK or US$40bn globally, at various times but is now seeking a more robust and nuanced figure for the economic cost of food crime in the UK.

There are not yet figures based on the definition of food crime that we are using here. The findings were checked by experienced researchers in this field (Professor Lisa Jack and Dr John Spink) and it is confirmed that these are the generally accepted figures. Each one has been widely quoted by media, industry, professional and academic speakers and writers. However, as we show below, each one is flawed and needs to be treated with caution. Each of the figures is based on extrapolation of a proxy for food fraud, rather than being based on evidence of the costs of criminal activity.

2.2.1 An evaluation of each of the generally accepted figures related to food crime

Grocery Manufacturer's Association US$10-15bn per year in the USA

In 2010, the Grocery Manufacturer's Association in the USA produced an estimate of the possible cost of food fraud to its members. The main problem with the GMA (2010) figure, which is very widely quoted, is that it includes food safety incidents and product recalls, as well as what would be better termed food defence events. It does not adequately separate out fraudulent activity.

The GMA (2010) figure of US$10-15billion is an evaluation of potential impact on food and drink industry organisations rather than on economy or society. It is a heuristic rather than an accurate calculation but serves the purpose of the report, which is to encourage US manufacturers to improve their food protection systems based on growing awareness of real emerging issues in the industry.

Specifically, GMA (2010) looks at EMA – which in their definition includes substitution, mislabelling and giving false product information - and counterfeiting. Their methodology used 100 interviews with senior management, 50 responses to a nationwide survey, a database of 150 incidents of food fraud and drew on the expertise of consultants. The impact of EMA and counterfeiting is assessed as industry costs: insolvency; brand damage; lost revenue/market share; increased costs from investigation, legal cases, damages and other costs; and loss in share price. This is relative to the size of the product footprint; scale of the incident; toxicity of adulterant or pathogen and the application of regulations. A similar set of conditions is found in the NSF (2015) report.

The following table extracted from GMA (2010) is based on product recall and legal costs data from 2004-2009, from food safety incidents which include adulterations. The

breakdown of these costs are not specified in the report and the assumption is that all the cases mentioned are EMA or counterfeiting, whereas the *E.coli* and Salmonella cases, even if they involve passing off products that are known to be contaminated (see Manning and Soon 2016) are breaches of food safety and trades description law. It is arguable whether or not they should be treated as EMA, and the report does not provide the reasoning behind the decision to include them.

Table 1 Product Recall and Legal Costs - Adapted from GMA (2010).

Food Incident	**Product Recall and Legal Costs**
Sudan Dye in Spices 2004	$418bn
E-coli in juice; Counterfeit Turkish Alcohol; Sudan Red in Sauces 2005	$908bn
Salmonella in Chocolate; Adulteration of Pomegranate juice; Aflatoxins in pet foods 2006	$162bn
Melamine in pet food; lead paint in toys; Diethylene glycol in toothpaste 2007	$3,400bn
Melamine in milk; Salmonella in peanuts 2008/9	$11,400 (Melamine alone given as $10,000bn)
Total	**$16,288bn**

GMA (2010) also looks at the increasing number of product recalls in the USA during the period and the costs incurred. For a large company, it is estimated – based on a number of recalls and bankruptcies between 1987-2009 – that the impact would be between US$80million and US$2billion. They work on the basis that there are around 300 recalls per year in the USA, resulting in 75 million food borne illnesses, 325,000 hospitalisations and 5,000 deaths. The problem is that the recall data includes all recalls and doesn't extract those related to EMA and counterfeiting. Therefore, it is not clear whether the 300 recalls they use as a basis for the calculation are all the result of food crime. Benchmarking their findings against the Melamine scandal, which they claim lost

US$10bn and resulted in 50,000 hospitalisations, gives a baseline of US$10bn. The US$15bn upper limit calculation is the figures for 2007 and 2008 in Table 1 combined.

Therefore, we can conclude that the GMA (2010) calculations only result in a rough estimate of impact but as indicated above, their purpose is to galvanise the food industry into taking food crime prevention measures. It is not designed to give an economic cost of food crime for a country. The difficulty of applying their methodology is the extent to which the data can be obtained and made accessible. It would require an extensive collection of survey and panel data under conditions of anonymity and confidentiality, and sufficient detail in product recall data to be able to isolate food crime incidents from other product recall data.

PwC US$30-40bn globally per year

The PwC figure of $30-40billion globally is based on a very simple projection. It makes an assumption that counterfeiting can be used as a proxy for all EMA. This is based on figures for the incidence of counterfeiting (of all goods) which is widely held to be 5-7% of global trade (CIB, 1997 quoted in Spink and Fejes, 2012).

The problem, of course, is that not all food fraud is counterfeiting, and we do not have evidence that food fraud grows in proportion with the growth in global trade. Essentially, it is another heuristic rather than an economically sound calculation of effect. The heuristic is useful in getting regulatory bodies and service industries such as audit and assurance services to focus on the increasing risk that food crime (or economically motivated adulteration in this context) might be endemic in society.

Taking the global food trade figure for developed countries c.2010 of $589billion as found in the UN COMTRADE Database (ITSY, 2011), this gives roughly US$29-41 billion. The figure was given by Spink in a presentation to the GFSI/PwC around 2013 (pers. comm.) and then quoted widely thereafter (for example, in Johnson, 2014).

The global or international food trade figure is very difficult to locate but various FAO reports give the figure as US$380billion 1997, US$426billion in 2000 and US$1.5 trillion in 2017. In the EU, statements give food trade in Europe as 255 billion euros in 2017 (EU, 2018), which includes livestock. Applying the 5-7% heuristic we would have a figure for annual food crime of 18 billion euro in Europe in 2017-18. However, the

figures are an estimate and contain no detailed methodology for analysing the economic impact of food crime.

Our project is not concerned initially with estimating the magnitude of food crime, although the proposed Phase 2 of the project may take this further. However, exactly the same constraints would be found as with the OECD (2007) attempts to quantify the extent of counterfeiting and piracy. Operation Opson, which records the levels of counterfeit and substandard food and beverage internationally, may provide a basis for seizures in this one area of food crime.[4]

Center for Counter Fraud Studies/BDO £11.2 billion per year in the UK

Although based on audited data for the food industry, this does not isolate the issue of food fraud. It is a generic figure based on the incidence of all fraud across a range of organisations and is applied to the aggregate turnover of the top 75 food firms by turnover in the UK. It is designed to alert food organisations to the need for a programme of counter fraud measures in the industry (which is not well protected in terms of management control over fraud) that would counter not just food fraud but all fraud.

The final commonly quoted figure is based on a longitudinal study of fraud costs in UK and European organisations, both in the private and public sectors. It consists of a database of audited fraud costs that contains data from around 1500 organisations across all sectors. This includes all types of organisational fraud, including consumer fraud, employee fraud, supplier and purchasing fraud as well as food fraud (as it is termed in the report). The Cost of Fraud derived from this database is published biannually by the Centre for Counter Fraud Studies and the accountancy firm Crowe. In 2015, the average cost of fraud for across all organisations in the database was 5.47% of turnover. Applying this figure to the turnover of the top 75 UK food organisations, around £200billion, this gives an estimated cost of fraud in the food and drink sector of £11.2billion in 2014 (Gee, Jack and Button, 2015). In 2017, this had been adjusted to around £12billion based on an average of 5.6% of turnover (Gee et al, 2017).

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[4] Operation Opson

Although the figure does provide a very generic estimate, it is assumed that fraud within the food industry is likely to be correlated with food crime. However, more detailed data collection would be needed to separate out the costs and the nature of fraud in the food industry.

2.3 Approaches to economic evaluation of crimes

This project includes evaluations of the economic impact and the determinants of food crime. In order to study the determinants of food crime, we follow Becker's (1968) model and hypothesise that producers are more likely to commit fraud if their benefits are higher and the costs of committing fraud lower. Furthermore, what we are looking for is determinants of food fraud that vary over time rather than only across subsectors of the food industry, as this would allow us to distinguish the impact of these determinants from subsector-specific characteristics. Depending on data availability, such a study might be conducted on firm level (explaining an observed firm's decision of whether to commit food fraud) or on subsector level (explaining the fraud rate in a particular subsector of the food industry). In our context, this would mean that, for instance, the following effects affect a firm's propensity to commit food fraud:

1) Most obviously, (exogenous) changes in the resources devoted to inspections in a certain subsector (such as in a crackdown) will affect deterrence.
2) The size of the punishment when caught committing food fraud may also vary across firms. For instance, a firm that is struggling financially may not be able to pay a fine, and a loss of reputation might be less relevant as the firm would have been in difficulties even without being exposed as fraudster. However, this type of determinant is only available in a study on firm level.
3) A high demand for the product of a criminal activity increases the incentives to engage in it. In the context of food fraud, this would mean that, for instance, a surge in the demand for branded food or drinks increases the benefit from mislabelling.

2.3.1 Disadvantages of this approach

A disadvantage of this theory-led route is that we might not be able to find suitable proxies for the hypothesised determinants of food fraud. Furthermore, even if we are able to find them for some subsectors, they may not be universally available. As the ultimate goal of our analysis is to find determinants of food fraud that the FSA will be able to use to detect food fraud, a second potential route is to analyse the relationship between a firm's decision to commit food fraud and all the potential market and firm characteristics that are universally available to the FSA, in a more explorative way.

A general problem of studying determinants of food fraud rates across subsectors of the food industry with data on the subsector level is under-reporting of food fraud, i.e., some victims choose not to report the fraud for various reasons. This is not necessarily a problem if the sample of reported frauds is a representative sample of all committed frauds. However, if the selection of reported crimes systematically varies with one of the variables of interest, using such data without any correction would lead to biased estimates. In our case, this is relevant as reporting rates across subsectors may be different depending on how easy it is for victims to detect that they have been defrauded. We propose to use the rate of detected frauds in all inspected firms to approximate the rate of committed frauds in all firms.

2.3.2 Other approaches

Since the seminal work of Becker (1968), there have been numerous studies empirically estimating the impact of the probability of conviction or severity of punishment (amongst other factors) on crime rates. Estimation is often conducted with 2 or 3 stage ordinary least squares econometric modelling. When combined with a dataset constructed over time (panel data) econometric modelling can account for intricate endogenous relationships between the factors crime rates to provide a reliable estimate (Cornwell and Turnbull, 1994).

Indeed, in this light Oberholzer-Gee and Strumpf (2007) apply a 2 stage least squares fixed effects panel estimation to measure the impact of illegal file sharing of music on the sales of legitimate music sales. The 2 stages to the estimation method allows the use of an instrument to replace a data variable that is closely correlated to another. In this case, the problem arises due to correlation between prices and product quality.

Such an econometric method can be applied to the conceptual framework the project will develop, with an aim to estimate the impact of crime on the UK economy.

Given that the key concerns are impacts of food crime on consumers, industry, Government, and the economy, we can provide explicit details where data are available and the assumptions made where data are not yet available. In this respect, it is noted that identification of the market for 'illegal' food, a consumers' substitution rate between 'illegal' and normal food, and the value or price of 'illegal' food are well known limitations to providing an empirical estimate of the impact of food crime. To this end, our conceptual framework and empirical method will attempt to address these shortfalls.

2.3.4 Constructing the analysis

As for the quantification of the economic impact of food crime, there is a large volume of literature that assesses the costs of various types of crime by splitting these costs into several categories and collecting data for these categories from various sources. To the best of our knowledge, however, there is no study that applies this method to the quantification of the cost of food crime. For instance, McCollister et al. (2010) calculate costs of crime for a range of specific crimes, using a combination of cost-of-illness and jury compensation methods known from previous studies. They classify potential costs into 4 categories:

1. Victim costs: Direct economic losses suffered by crime victims, including medical care costs, lost earnings, and property loss/damage.
2. Criminal justice system costs: Local, state, and federal government funds spent on police protection, legal and adjudication services, and corrections programs, including incarceration.
3. Crime career costs: Opportunity costs associated with the criminal's choice to engage in illegal rather than legal and productive activities.
4. Intangible costs: Indirect losses suffered by crime victims, including pain and suffering, decreased quality of life, and psychological distress.

One of the crimes studied in this paper is "forgery and counterfeiting", but our plans go beyond their analysis of this case in two ways: First, in the case of food fraud, there is a risk of injury to victims. Secondly, we are planning to take into account harm done to

genuine producers who compete with the fraudster in the market. We think that both of these costs would be part of “Victim costs”.

The analysis proceeds in three steps: First, the number of offenses is approximated. McCollister et al. (2010) use statistics of arrests by crimes and, for a subsample (a small number of US states in their case) for which actual offense numbers exist, calculate the ratio of offenses to arrests and use this ratio to extrapolate the number of offenses in the overall sample (based on the number of arrests).

Second, the tangible victim costs are obtained directly from publicly available data (in their case of US data, from DOJ). Another kind of tangible costs is the costs of the criminal justice system, including those of police protection, of the legal process, and of punishment. Police protection costs are assumed to be uniform across all crimes, the legal process is allocated to crimes using the crime’s share in total arrests, and the number of inmates is approximated using arrest figures. A third kind of tangible costs is crime career costs, which are approximated by assuming that offenders would have worked at minimum wage had they not become criminals and potentially incarcerated.

Third, intangible costs such as pain-and-suffering are obtained as the difference between jury awards and the victim’s direct loss (the “jury compensation” method). Cohen (2004), explains this method in greater detail.

An alternative approach to estimating the impact on the economy is to use a computable general equilibrium method. Often considered as ‘top down’ view compared to econometric modelling, a general equilibrium approach can estimate an impact across the economy as a whole. Here each agent within the economy are represented: consumers, industry, Government, foreign trade. A system of equations representing the above agents are solved simultaneously to obtain a general equilibrium of the economy. National Input - Output data and Income Expenditure data can be used to provide the detailed information about how the impact ripples through other industry sectors. Together, the data and mathematical framework provide a numerical value of the economy wide impact of changes that influence agents (Hosoe, Gasawa & Hashimoto, 2010). Furlong (1987) and later Fender (1999) develop a general equilibrium specification specifically designed to model fundamental nature of the interactions among criminals, victims, and law enforcement. Such a model can be used

accommodate the conceptual framework this project will develop and to test the wider economic impacts of a variety of scenarios.

2.3.5 Conclusion

We will follow the former method detailed in McCollister et al. (2010) and quantify the various categories of potential costs of food crime. Furthermore, we will introduce an additional category that has not been considered by the aforementioned literature and that reflects the economic nature of food crime. As the producer of counterfeit food, for instance, competes with genuine producers in a market, the counterfeit version of the good will crowd out some of the genuine version, so that food crime will have a negative effect on the efficiency of the market.

Beyond the crowding-out effect that we consider, Marketing scholars argue that the presence of counterfeits in a market reduces customers' trust in the genuine good. Furthermore, there is theoretical (Grossman and Shapiro, 1998) and empirical literature (Qian, 2008) discussing the impact of counterfeits on genuine producers in a more general (i.e. not food-related) type of market. There is evidence to suggest a similar loss in consumer confidence following the European horsemeat scandal, where Barnett et al (2016) found that consumers "…claimed that their confidence in processed foods containing meat was lower than before the incident" (p.721) and "…that rebuilding consumer confidence in processed meat products following a food adulteration episode is a multifaceted and difficult process" (Ibid.).

3. A framework for quantifying the cost of food crime

We provide a recommended approach which is yet to be matched with the appropriate data, in doing so we make use of McCollister et al. (2010) to provide the basic framework for estimating the economic cost of crime, as summarised above. However, we depart from this work in two major areas:

Firstly, we define each model element for use within the food crime context. The McCollister et al. (2010) approach is a 'bottom up' cost method that aggregates the individual cost category elements. These elements need to be carefully defined for the specific context of the crime(s) being examined. Whilst 'fraud' and 'counterfeiting' are crimes investigated McCollister et al. (2010), some cost element are not applicable to food crime (such as, damage to property) and other obvious issues are not considered (such as, loss of profits of genuine firms). As such, the model does not directly translate for use with estimating the cost of food crime.

Secondly, we include an approach to estimate the loss of profits for genuine (non-criminal) firms in the market. We coin this element Market Costs. A distinctive feature of food crime is that it occurs alongside legal economic activities, which means that legal and illegal activities will impact on each other. If criminal firms are better able to reduce product prices, this can result in the loss of profits for the genuine competing firms.

From a consumer's perspective, some types of food crime may, therefore, be viewed as a problem of purchasing an item of unknown quality – it might be a genuine, high quality item or a low-quality counterfeit or an item containing lower quality substitutions for ingredients. Therefore, if a consumer happens to end up with a low-quality item, her willingness to pay for that item had she known the quality might well have been way below the price that she has actually paid for it. From an economic point of view, this does not necessarily constitute a social cost per se, as this does not involve any resources lost for society but rather money changing hands, i.e., the amount overpaid remains in the economy. By contrast, we focus on quantifying the net loss for society as a whole, i.e., consequences of food crime that reduce the overall resources available in the economy.

With a view to aid the immediate usefulness of this approach, we offer 'simplifications' to the quantifying approaches. These simplifications accommodate the data currently

available (lack of), moving from the bottom-up approach to a more generalised calculation. These are intended as a stepping-stone towards the more detailed method and it is important to note the trade-off between the accuracy of the calculation and the level of complexity.

Our proposed framework for estimating the economic cost of food crime is outlined below. In turn, we define each element, provide an approach to calculation along with a simplifications where appropriate, and the potential data sources. Appendix A tabularises.

1. Victim costs: Direct economic losses suffered by crime victims, including medical care costs and lost earnings.
2. Criminal justice system costs: Costs of anti-food crime activities, legal and adjudication services, and corrections programs including incarceration.
3. Crime career costs: Opportunity costs associated with the criminal's choice to engage in illegal rather than legal and productive activities.
4. Intangible costs: Indirect losses suffered by crime victims, including pain and suffering, decreased quality of life, and psychological distress.
5. Market costs: Loss of profits for genuine firms.

3.1 Quantifying the "Victim Cost" of food crime

Victim costs are the direct economic losses suffered by food crime victims and include the health care costs and lost earnings.

3.1.1 Health care cost

Human consumption of criminalised food may cause health related issues. Historical cases indicate that health problems can range from no obvious symptoms through to mortality. The incurred cost of health care stemming from consumption of criminalised food will depend on the medical severity, the number of cases treated, and the cost per treatment.

The base calculation is a multiplication of the number of cases related to food crime by the health care cost per case. Where the health care cost per case is identified from the

medical severity of consuming criminalised food and the associated UK health care expenditure for treatment[5].

Medical severity: Everstine et al. (2017) categorised food fraud related adulterants based on the potential of the ingredients to be hazardous to human health if consumed. These classifications are held in the Food Fraud Database developed by the U.S. Pharmacopeia Convention (USP)[6] and can be used to measure medical severity and frequency of incidents.

Number of cases: The above dataset will also provide up to date information on known cases, counterfeit food, for example. As such, the number of known cases can be taken directly from this source. Given that this dataset is available at a cost, an immediately available method would be to approximate the number of treatment cases related to food crime by using market demand information (discussed under Market Costs) combined with assuming a proportion of the product market will contain criminalised food.

Health care expenditure: To our knowledge there is no publicly available information on health care costs related to food crime. In its place, the next most useful information for this calculation is the average person cost of each type of illness (foodborne disease, allergic reactions or wider, depending on the desire of the researchers). In the absence of illness specific data, broader UK healthcare expenditures are available from the

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[5] Whilst some health care costs may not be incurred per-treatment by the victim if receiving services paid from public expenditure, these remain as a direct cost to the victim in this model for the following reasons: So that there is no requirement to distinguish private or public health care services and those covered by insurance or otherwise; health care costs are highly correlated with loss of earnings, so a reclassification of cost-type (to say, Government costs) would appear cumbersome when combined with the previous issue.

[6] Food Fraud Database

Office for National Statistics[7] and the OECD[8] which can be used to identify an average cost of healthcare provision by health status.

3.1.2 Loss of earnings (consumers)

If consumption of criminalised food causes health problems, then the victim may be forced to take absence from their usual working pattern. This will cause a reduction in productivity that is either carried by the employee or the firm, depending on where the burden for sick leave costs fall. The total loss of earnings incurred due to illness depends on the medical severity, the number of cases, and earned wages. This is distinct from quality of life adjustments from physical and psychological suffering, these are discussed in intangible costs.

The calculation is the average present value of earnings. This can be calculated using the length of time and value of wages information, discounted at a chosen rate in order to capture inflation. This method assumes there will be no changes in future life expectancy or earnings growth.

Time length of the loss of earnings: This will depend on the medical severity information. The lengths of suffering for each type of harm are discussed in Dolan et al. (2005), although not food crime specific, these can be used as an approximate value (Dolan et al., 2005 is further discussed in Intangible Costs). In the case of mortality, the maximum average working life of 39.2 years[9] can be used accurately if the average age of mortality is known.

Number of cases: Information used in health care costs can also be used here.

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[7] Healthcare expenditure, UK Health Accounts 2017

[8] Health expenditure and financing

[9] Duration of working life statistics

Earned wages: Median annual pay can be taken from the Annual Survey of Hours and Earnings (ASHE)[10]. Using the aggregated median assumes that those affected by food crime have an average earning potential.

3.1.3 Loss of property (firms in supply chain)

Historical cases have shown that criminalised food can enter a supply chain at various points. A firm may unwillingly purchase and sell on criminalised food. If the crime is detected and food disposed of, the immediate financial impact on the firm is the cost of purchases. If the altered food remains undetected and sold on, then the firm, once victim, becomes the criminal (unknowingly) and faces reputation costs and legal consequences (for not detecting the crime) if later detected by any stakeholder involved.

Detected purchase costs: Data may differ depending on what location the firm is within the supply chain. Figure 1 of Brooks et al. (2017), for example, illustrates the complex nature of a supply chain in the context of the horsemeat incident in 2013. Individual firm level information will provide a clearer estimate but if this is not available, then the approximation of the cost of loss of earnings at final market value can be weighted by the Gross Value Added of the sector's intermediary output. This approach will avoid over estimating the value of loss to an intermediary firm based on the final market value of the food. The sector wide intermediary output is provided by the Office for National Statistics supply and use tables[11].

Reputation costs: It is possible to see changes in a firm's reputation by fluctuations in the share price immediately following the circulation of such news, whilst acknowledging that other factors may be influential. This information will allow a calculation of change in the firm's market value.

[10] Official labour market statistics

[11] Supply and use tables

Court ordered fines: Fines placed on firms can be obtained from court records[12]. This information is available for court cases held in the UK. Knowledge of the precise firms involved is needed.

3.2 Quantifying the "Criminal justice system" costs of food crime

Costs of anti food crime activities (ex ante), legal and adjudication services, and corrections programs including incarceration (ex post).

3.2.1 Prevention of food crime (ex ante)

This is the cost to all organisations, private, public, and NGO, in attempting to prevent food crime. Defining prevention as activities before a crime has necessarily taken place.

Holding to the definition of food crime used on this model, these costs should be distinct from activities to promote food safety more broadly (or any activity that is not considered intentional deception for economic gain). However, when considering some of the measures in place from governing bodies, it is apparent that there are resources common to both safety and crime. For example, the EU Rapid Alert System for Food and Feed[13] provides a platform for sharing information between member organisations (FSA included), this can be useful in reducing the risk of unsafe food and also mitigating criminal activities.

It would be desirable to apportion total prevention costs to each of the crime categories. However, these costs are likely presented only as a total cost, say the cost of an organisation such as the FSA National Food Crime Unit, for example. As such, the cost of food crime prevention and detection measures could be approximated under the assumption that these activities do not vary across specific categories of food crime on the premise that they are costs incurred ex-ante.

Recommendations from Elliot (2014) stress the importance of Government involvement in food crime prevention. Specifically, recommendation 1 p17, lists areas for the Government and industry to develop. More widely, global efforts developed by customs

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[12] The Law Pages

[13] RASFF – Food and Feed Safety Alerts

agencies through the World Customs Organization (WCO) such as the reporting framework Customs Enforcement Network (CEN)[14], can be included in prevention costs (Avery, 2008). Costs of such activities are not easily identifiable from publicly available information and are perhaps obtainable from Government sources, perhaps from the FSA. For example, the cost of running the National Fraud Initiative is briefly reported as £2.7m per year[15]. As such, we recommend that the FSA constructs a list of institutions and government bodies to be included in this and the information currently available.

Private firms are often mentioned for spending substantial resources combating breaches of property right infringement or fraudulent activity. However, there are no consistent methods, to our knowledge, for indicating the resources used across firms specifically for prevention of food crime. As such, we provide a recommendation that the FSA considers conducting a firm level survey to obtain data on resources used to help prevent food crime. The precise nature and contents of the survey requires further research.

Prevention of food crime: In the absence of the data mentioned above, a minimum threshold cost can be used. In this view, the cost of running the FSA would provide a minimum cost of food crime prevention in the UK. The purposes of the FSA are much broader and as such, this approximate measurement may not be fully appropriate.

3.2.2 Legal, adjudication costs and corrections costs (ex post)

These are the legal, adjudication, and corrections costs that are incurred post-offense, and excludes policing.

In the absence of clear information relating specifically to food crime, the calculation is to weight the total UK legal, adjudication, and corrections costs for incarcerated criminals by the contribution of arrests, court appearances, and proportion of inmates derived from food crime. This would provide a per food crime cost and would assume homogenous costs across settings, following the approach used by Heeks et al. (2018).

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[14] Customs Enforcement Network

[15] Government saves £300m in two years by preventing fraud and error

Legal costs: The Law Society in 2018 published an analysis on the cost of a day in court[16], however, HM Courts and Tribunal Service publishes annual accounts showing the total court expenditure[17]. Using this data, the Institute for Government provide summary analyses[18].

Correction costs: The Ministry of Justice provides costs per prison place[19] and also annual report accounts[20]. The above method could be adapted in future to food crime specific correction costs if data become available. For example, the Ministry of Justice publishes headline statistics on prisoner number on a regular basis and may respond favourably to more detailed ad-hoc requests for food crime related statistics[21].

3.3 Quantifying the "Crime career" costs

If an individual enters the labour force then they are a productive factor that contributes to the growth of the economy. The crime career cost is the cost to the economy caused by an individual choosing to be employed in activities that don't contribute to the economy. More precisely, this is the loss of productivity associated with those choosing to spend time engaging in illegal activities that do not contribute to Gross Domestic Product.

Productivity losses can be approximated by combining lifetime expected earnings information and the length of time engaged in criminal activity and then in incarceration (if convicted).

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16 Cost of day in court analysis

17 HM Courts & Tribunals Service annual report and accounts 2017 to 2018

18 Criminal courts – Performance tracker 2019

19 Prison performance statistics 2017 to 2018

20 Ministry of Justice Annual report and Accounts 2018 to 2019

21 Statistics at MOJ

Expected earnings: This can be taken from the information used to calculate loss of earnings.

Length of time: To be precise about this cost would require knowledge of all food related criminal activities and the length of time of engagement, which if known would likely to cease existing due to police intervention. Instead, it is possible to use the length of prison sentence awarded to generate person years served. This approach would assume all inmates would be equally productive for the economy is otherwise working in a legal occupation. As from the previous section, data are available from the Ministry of Justice. Here there is a dependency on identifying all food crime; this is a consideration that needs to be addressed for the practical delivery of this model.

3.4 Quantifying the "Intangible" costs

Some victims of food crime may suffer pain or psychological distress. Whilst there is no direct economic cost inferred, this intangible cost can be estimated by considering the decreased quality derived from physical or mental suffering. For some crimes, court records will demonstrate the financial sums awarded to victims as compensation for such suffering.

If these records are not suitable for a particular food crime (as perhaps the crime would not appear in court), then a popular approach to providing a value for these intangible costs is to calculate the Quality of Adjusted Life Years (QALY) of victims (Dolan et al., 2005). Whilst this approach is usually used for violent crimes, there can be medical consequences associated with a food crime which justify its use. Heeks et al. (2018) uses this approach in combination with the Crime Survey for England and Wales database[22]. Our suggestion is to consider further research into the idea of including food crime within the Crime Survey for England and Wales. Whilst fraud appears within the questions, there is no explicit way of using this survey to support information regarding food crime. Such a survey identifies consumers that are aware of being a victim of food crime, therefore may underrepresent the true level of crime.

[22] Crime survey for England and Wales

The likelihood of physical or mental suffering can be approximated using the medical severity and market demand information from Health Care Costs. Information on the associated level of harm can be approximated from the injury disability weights calculated by Salomon et al. (2015). The duration of harm is discussed in Dolan et al. (2005), this lacks food crime specific physical injuries (allergic reactions, consuming harmful substances etc.) as these are based on crimes such as assault, but an assumption can be made using a combination of harm categories. The value of a full and healthy year (value of life year) can be taken from the Department of Health's estimate (Glover and Henderson, 2010). There are a variety of ways to estimate which are well discussed by OECD (2012) and more recently by Kniesner et al. (2019).

3.5 Quantifying the "Market Cost" of food crime

A distinctive feature of food crime is that it occurs alongside legal economic activities, which means that legal and illegal activities will impact on each other. Food crime can only be successful if consumers are unaware of it at the time of purchase, so that counterfeit produce will compete with genuine items in the same market. Fraudsters typically have a competitive advantage over genuine producers as the main motivation for food crime is to save some of the production costs that genuine producers incur. Therefore, the presence of counterfeit items will crowd out some genuine items.

We have analysed this effect within a simple oligopoly model with n genuine producers. A small amount of counterfeit is offered on the market, which implies that there is less demand left for the genuine producers for any given price. This reduces marginal revenue of all genuine producers and, therefore, their incentives to supply the good.

If the number n of genuine producers is very large, competition is perfect, i.e., marginal revenue is equal to the price, so that one unit of counterfeit will crowd out exactly one unit of the genuine good. With incomplete competition, there is less incentive to provide the good, so that one unit of counterfeit will crowd out less than one unit of the genuine good. The analysis in Appendix B shows that, under the assumption of a linear demand curve and constant marginal costs (which may potentially differ across genuine firms), one unit of counterfeit crowds out half a unit of a monopolistic genuine producer's quantity. More generally, the impact will be somewhere between both extremes: If there

are n genuine producers, one unit of counterfeit crowds out n/(n+1) of a unit of the genuine good.

In order to understand the welfare effect of the presence of the counterfeit in the market, we need to make a few more assumptions. First, it is plausible to assume that the counterfeit is of no value to the customer. Then, producing another marginal unit of the counterfeit will waste resources equal to the marginal cost of the counterfeit producer. The price that the customer pay for the counterfeit is welfare neutral from a market perspective. It is as if the fraudster had stolen that amount of money from the customer. Therefore, the price paid for the counterfeit belongs to victim costs rather than market costs.

Furthermore, we need to add the social cost of the aforementioned crowding out of the genuine good. The cutting-edge method for estimating welfare effects of market entry (which is similar to the effect of the removal of the counterfeit from our market) involves structural estimation of firm level data (see, for instance, Branstetter et al. (2016) for a recent example). Unfortunately, while data relating to consumers (price and demand) are easily available, we are not aware of any source for firm-level cost data for most food categories. In our case, however, the thought experiment is the impact of marginal changes in the deterrence of food crime (rather than market entry of a number of new competitors in the aforementioned literature). Therefore, it is sufficient to understand the benefit and cost of a marginal unit of the genuine good being crowded out.

The customer's willingness to pay for the last marginal unit of the genuine good is, in any market, equal to the price. Therefore, the social cost of the crowding out is equal to the social benefit (equal to the price) less social costs (the marginal cost), times the quantity that is crowded out. Again, we need some firm-level data on the marginal cost. However, if there was access to data on the average marginal costs in a particular food industry, then these average marginal costs could be used to approximate the average welfare loss from crowding out equal to

(Price – Average Marginal Cost of Genuine Firms) * n / (n+1).

If firm-level cost data are not available, it might still be possible to approximate the "Market Cost" of food crime when assuming that all firms have identical marginal costs. In that case, it is well-known that firms' first-order conditions of optimal quantity can be

expressed in terms of the price elasticity of demand ε = n * Relative markup, where relative markup means the ratio between the absolute markup (the difference between the price and marginal cost) and the price. In other words, in a Cournot oligopoly with n identical (genuine) firms, the absolute markup is always equal to ε * Price / n. As we have argued before that the total welfare cost of crowding out is equal to the absolute markup times the quantity that is crowded out, which in turn is n/(n+1), this yields the "Market cost" of food crime to be equal to

ε * Price / (n+1).

In order to quantify these, we still need the price elasticity of demand, which we can, however, obtain straightforwardly using data from the Living Cost and Food Survey[23] and the method of "Almost Ideal Demand Systems" by Deaton and Muellbauer (1980).

The method that we have just discussed has assumed that consumers cannot observe whether a producer is genuine or fraudulent. The consequences of food crime for genuine producers are even more severe if consumers can identify some other producers who are definitely genuine. In that case, demand will switch even more from genuine, but unidentifiable, towards identifiably genuine producers. This distinction is important in the context of international trade, when a food crime scandal in one country causes a shift in demand for this item from production in the affected country to production in other countries, thereby inflicting even greater harm on the genuine producers in the affected country.

3.5.1 A note on method and the multiplier

Wickramasekera et al. (2015) provides an insightful review of studies estimating the cost of crime more broadly. Costs for each crime category are estimated by each study and contribute to the total cost of crime. Whilst food crime is not explicitly considered, perhaps the nearest crime category of fraud is estimated by several studies. Adjusting these estimates to GBP (based on exchange rates 12/12/19), the estimates vary from approximately £585 million to £939,242 million. As noted by Iqbal et al. (2019), the reason for such variance in estimates are the underlying methodology used and the use

[23] Living costs and food survey

(or exclusion) of particular categories of crime costs. Broadly, there are four approaches to estimating the cost of crime: a bottom-up cost method; contingent valuation; hedonic pricing; and economic modelling of the wider economy.

We favour the bottom-up approach as this allows for a framework that can translate across borders and focus exclusively on individual types of food crime, such as adulteration, as well as the overall. We follow the framework of McCollister et al (2010) (with some additions) as this provides the most comprehensive consideration of categories of crime costs.

In any economic impact estimation, there is consideration of direct, indirect and multiplying costs. The direct costs are those we considered under ‘victim’ and ‘criminal justice system’. The indirect costs are those we considered in ‘crime career’ and ‘intangible’. The framework we present provides an opportunity to add on the multiplying effects on the wider economy. This is the follow on of direct costs, for example, lost earnings cannot be spent on good and services. The use of a multiplier is often misleading and unhelpful in showing the costs of crime as there are no reasonable data to estimate such costs and assuming a multiplying figure leads to severe widening of confidence intervals. Iqbal et al. (2019), for example, assumes a multiplying effect that doubles the direct costs. There is no multiplier value that is easy to justify.

4. Use of AI and other big data technologies to collate and calculate cost of food crime.

In this section, we indicate how the data collection and analysis could be facilitated by the use of new technologies, to allow the calculations based on the model can be updated more easily and cost effectively.

4.1 Data Collection

Based on the food crime framework model, numerous data sources have been identified to help build the model in Appendix A. For this model to be effective, a period of data collection will need to be initiated. This would need input from domain experts as well as data engineers. A database should be set up to store the data identified in Appendix A. Depending on the data source, some pre-processing might be required to convert the data into a usable format. Initially this will require manual effort but over the long term, automated scripts would be developed to extract new data and pre-process it. Cloud based technologies such as Amazon Web Services or Google Cloud would be suitable hosts for the data and the model.

Data related assumptions would need to be careful collated and integrated into the model so that upper and lower bounds on the estimated cost of food fraud could be established.

4.2 Data Analysis

The importance of data collection and collation should not be underestimated. With accurate data and an understanding of its limitations, significant value can be derived from it. Examples include …

- Estimated Cost of Food Fraud: Whilst the estimated number will be valuable, further analysis of the model components will identify the key contributors to this total cost
- Estimated Impact of Food Crime: By considering costs such as …
    - Victim Costs,
    - Criminal Justice System Costs,
    - Intangible Costs,

it would be possible to determine which food types/products/categories have greater impact potentials in terms of cost than others.

- Estimate the Likelihood of Food Fraud for Different Food Types: By considering costs such as:
    - Career Crime Costs
    - Market Costs

it would be possible to identify which food types/categories are the most attractive for food fraud criminals to target. Clustering techniques such as k-means could be used to cluster different food types to identify which types have elements in common. This information, tracked and plotted over time, could allow the FSA to better allocate resources to pre-empt food fraud.

4.2.1 Conclusion

Machine learning and data science are powerful tools, but they are only as powerful as the data that is collected. Efforts should be made to collect the data mentioned and pre-process it so it is in the right format and aggregated with other sources.

5. Steps required in Phase 2

In order to implement our model and achieve the requirements of Phase 2 of the project, to be commissioned at a later date, which use the outputs of Phase 1 to construct and populate a model and necessarily provide working estimates of the impacts of food crime to the UK economy, we suggest that the following steps will be needed:

Table 2: Suggested Gantt chart for Phase 2 of the project

Task	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Source data required (see Appendix A), including negotiations to use databases that are run on a commercial basis								
Refine and test the model provided in the Phase 1 report								
Develop a specification for a database, including the use of machine learning to extract and organise data sourced from external sources. This would involve creating new datasets as indicated in Appendix A								
Build and test a computer-based prototype of the database								
Develop functions and algorithms to calculate the figures required automatically								
Robustness tests for figures calculated								
Writing reports and manuals, attending meetings and project management								

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7. Appendix A: Model cost elements and potential data sources

Victim costs

Model element	Agents concerned	Possible data	Source	Improvements
Health care costs	Government (NHS), health insurance firms, consumers	Medical severity from Food Fraud Database	https://decernis.com/solutions/food-fraud-database/	Needs further investigation for suitability of UK use, data behind pay wall.
		Market demand information from Living Cost and Food Survey	https://www.ons.gov.uk/peoplepopulationandcommunity/personalandhouseholdfinances/incomeandwealth/methodologies/livingcostsandfoodsurvey https://stats.oecd.org/index.aspx?DataSetCode=SHA	
		UK healthcare expenditures from UK Health Accounts, Office for National Statistics	https://www.ons.gov.uk/peoplepopulationandcommunity/healthandsocialcare/healthcaresystem/bulletins/ukhealthaccounts/2017	Identify costs by food crime categories.

Model element	Agents concerned	Possible data	Source	Improvements
Loss of earnings (consumers)	Consumers	Median annual pay can be taken from the Annual Survey of Hours and Earnings (ASHE)	https://www.nomisweb.co.uk/query/select/getdatasetbytheme.asp?theme=25	
		Time away from work approximated from medical severity	Dolan et al. (2005).	Specific food related harms need to be considered.
Loss of property (firms)	Firms	Final market demand information from Living Cost and Food Survey	https://www.ons.gov.uk/peoplepopulationandcommunity/personalandhouseholdfinances/incomeandwealth/methodologies/livingcostsandfoodsurvey	
		Gross Value Added of intermediary	https://www.ons.gov.uk/economy/nationalaccounts/supplyandusetables	Identify firm activities by restricted SIC codes.
		Share price changes (depends on exchange listing)	https://www.londonstockexchange.com/home/homepage.htm	Identify time points for breaking news stories.

Model element	Agents concerned	Possible data	Source	Improvements
		Court records (depends on country of court)	https://www.thelawpages.com/index.php	Identify costs by food crime categories.

Criminal justice system costs

Model element	Agents concerned	Possible data	Source	Improvements
Prevention of food crime (ex ante)	Government, NGOs, firms	Possible Government sources. Possible firm level survey or financial statements	https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/823160/1_Public_Spending_Statistics_July_2019.pdf	Needs collaboration within Government for sharing costs information. Firm level survey.
Legal, adjudication costs and corrections costs (ex poste)	Government	Ministry of Justice records	https://www.gov.uk/government/organisations/ministry-of-justice/about/statistics	Identify costs by food crime categories. Potentially one of the most challenging data sources to generate.
Crime career costs	Wider economy	Median annual pay can be taken from the Annual Survey of Hours and Earnings (ASHE)	https://www.nomisweb.co.uk/query/select/getdatasetbytheme.asp?theme=25	

Model element	Agents concerned	Possible data	Source	Improvements
		Length of prison sentence.	https://www.gov.uk/government/organisations/ministry-of-justice/about/statistics	Identify sentences by food crime categories.

Intangible costs

Model element	Agents concerned	Possible data	Source	Improvements
Decreased quality of life	Consumers	Medical severity from Food Fraud Database	https://decernis.com/solutions/food-fraud-database/	Add food crime to the Crime Survey for England and Wales. Noting the potential shortcomings given low consumer detection of fraud.
		Market demand information from Living Cost and Food Survey	https://www.ons.gov.uk/peoplepopulationandcommunity/personalandhouseholdfinances/incomeandwealth/methodologies/livingcostsandfoodsurvey	
		Level of harm: Disability weights	Salomon et al. (2015).	Specific food related harms need to be considered.

Model element	Agents concerned	Possible data	Source	Improvements
		Duration of harm	Dolan et al. (2005).	As immediately above.
		Value of life year	Kniesner. and Viscus (2019); Glover and Henderson (2010).	

Market cost

Model element	Agents concerned	Possible data	Source	Improvements
Loss of profit for genuine firms	Firms not engaging in food crime	Price and quantity of food products from Living Cost and Food Survey	https://www.ons.gov.uk/peoplepopulationandcommunity/personalandhouseholdfinances/incomeandwealth/methodologies/livingcostsandfoodsurvey	