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Differences in fraud vulnerability in various food supply chains and their tiers

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ABSTRACT

Food fraud results from the interaction of motivated offenders with opportunities, and lack of control measures. The vulnerability to food fraud varies across chain actors (tiers) though, but insights on prime fraud drivers and enablers, as well as chain areas where vulnerabilities might exist are lacking. In the current study the fish, meat, milk, olive oil, organic bananas, and spice supply chains were assessed for their fraud vulnerabilities. The differences and similarities in vulnerabilities across the supply chains, as well as between groups of chain actors were evaluated using the SSAFE food fraud vulnerability assessment tool. Multiple correspondence analysis and agglomerative hierarchical clustering were applied for exploratory data analysis, and differences between chains and actors were assessed by analysis of variance and post-hoc tests. Thirteen fraud factors related to opportunities and motivations scored high across all supply chains indicating their importance as fraud drivers and enablers. Control measures varied considerably across supply chains and actor groups, with technical (hard) controls generally being more in place than managerial (soft) controls. Approximately half of the fraud factors were impacted by the type of commodity chain, and one out of seven of the fraud factors by the actor group. From the current sample group overall fraud vulnerability appeared highest for the spice chain, which was followed by the olive oil, meat, fish, milk and organic banana chains. Among the actor groups, the wholesale/traders group appeared most vulnerable, followed by retailers and processors. The current results provide new insights in the fraud factors determining fraud vulnerability in various supply chains, and the (dis)similarities in fraud vulnerability across supply chains and actor groups which helps to combat future food fraud.

1. Introduction

Food fraud is a form of criminal behaviour, no matter the definition of crime. The consequences of food fraud are devastating. Food companies and their reputation are damaged, stories go viral, whole supply chains are painted with the same brush, consumer confidence erodes, markets collapse, and management and/or employees are fired, prosecuted, and locked up. The general effects show similarities with other corporate frauds (Kuang & Lee, 2017). Losses for individual businesses may include social losses & punishments, third party losses (e.g. extra testing), confidence losses, sales losses & over payment, as well as recall losses (Bindt, 2016). If we take the horsemeat affair as an example, it certainly had a huge economic impact: widespread product recalls and serious effects on all ground beef sales across Europe (Moyer, DeVries, & Spink, 2017). There is some popular belief that food fraud is mostly an external threat caused by organized crime groups seeking to permeate the food supply chain. Although politically convenient, in reality it is more often a problem within the food system itself and committed by legitimate food supply chain actors who make the most of criminal opportunities that arise (Lord, Flores Elizondo, & Spencer, 2017).

Fraud is the result of the interaction between motivated offenders, and the opportunities presented by victims and by those entrusted with controlling risks according to Levi (2012). Fraud vulnerability results from openings for undesirable events resulting

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from weaknesses or flaws related to the system (Spink, Ortega, Chen, & Wu, 2017). Further, criminogenic incentives can differ for the various tiers in production and distribution chains (Simpson, 2011). An assessment of the factors affecting this vulnerability is, therefore, the first step towards fraud prevention and mitigation. Food fraud vulnerability is defined by three key elements: opportunities, motivations, and control measures. These elements can be subdivided into technical opportunities, opportunities in time and place, economic drivers, culture and behaviour, technical control measures, and managerial control measures (van Ruth, Huisman, & Luning, 2017). A food fraud vulnerability assessment (FFVA) can identify areas in the food chain where vulnerabilities might exist. It can also determine the key drivers and enablers of the vulnerability in supply chains (Spink, Moyer, & Whelan, 2016). From the food fraud vulnerability concept of the three key elements described above, an FFVA tool was developed (SSAFE, 2017), and was made available as a free downloadable app (PwC, 2017).

Some commodities seem to be more associated with food fraud than others. An inventory of reports in the three global food fraud databases over the period 2008–2013 revealed that the six most frequently reported commodity groups were spices and herbs, olive oil, seafood, dairy products, meat, and other oils and fats (Weesepoel & van Ruth, 2015). In China, especially animal products have been surfacing often in media fraud reports in 2004–2014 (Zhang & Xue, 2016) and in the Netherlands the top 3 included meat, fish, and organic produce according to an analysis of media reports over the period 2008–2014 (van Wagenberg, Benninga, & van Ruth, 2015, p. 126).

The present study deals with fraud vulnerability across supply chains that have been reported often in the food fraud inventories since it appears that fraud is occurring in those chains. Fraud vulnerabilities in the fish, meat, milk, olive oil, organic banana, and spice supply chains were examined in order to understand the contributions of various fraud factors to the overall fraud vulnerability. Furthermore, we evaluated the differences and similarities between commodity supply chains, as well as between groups of actors (tiers) across chains (e.g. processors, retailers). Detailed examinations of differences within the specific chains are not considered for this particular paper. For the spices chain such a detailed evaluation has already been published previously (Silvis, van Ruth, van der Fels-Klerx, & Luning, 2017).

2. Materials and methods

2.1. The food supply chain networks and actor groups assessed

Businesses in supply chains of six commodities were assessed and compared for their fraud vulnerabilities. They involved (number of interviewed actors in brackets): fish (5), meat (5), milk (8), olive oil (8), organic bananas (8), and spices (8). The actors belonged to three actor groups: wholesalers (7), processors (22), and retailers (13). Wholesale included traders, importers, distributors, and auctions, i.e. all organizations that did not process the products but just passed them on in the chain. Processors included companies processing the primary product, such as olive oil, but also complex food manufacturers. Primary producers, such as farmers or fishermen were not involved.

2.2. The food fraud vulnerability assessment (FFVA)

Various factors contributing to food fraud have been identified and were collated in a practical FFVA (PwC, 2017; SSAFE, 2017). The assessment consists of 50 questions and associated three level answering grids (low-medium-high vulnerability). Each question relates to the previously identified fraud factors: 9 for opportunities, 20 for motivations, and 21 for control measures (Table 1). The assessment was developed and tested through an extensive, interactive and iterative process with representatives from the global food industry, retail, authorities, and scientific community (van Ruth et al., 2017). The assessments in the fish, milk, meat, olive oil, and organic banana chains were carried out as described previously (Silvis et al., 2017). Furthermore, the data of actors from the spice chain of a previous study were included as well (Silvis et al., 2017).

2.3. Data analysis

The answers to the questions, selected by the businesses, were transformed to a score system. For opportunities and motivations, a score of 3, 2, and 1 was assigned to high, medium, and low vulnerability situations, respectively. For control measures the reversed order was used. The answers/situations associated with the three vulnerability levels are presented in the FFVA tool for each fraud factor (PwC, 2017; SSAFE, 2017). The two questions on counterfeiting, question 6 and 7, were not further considered since they did not apply to the commodity chains examined. For exploratory analysis, multiple correspondence analysis (MCA) and agglomerative hierarchical clustering (AHC) was applied. Opportunities and motivations related fraud factors were considered prime drivers and enhancers if their scores exceeded the average for either the opportunities or motivations group. Furthermore, to investigate the specific differences between the supply chains (fish, meat, milk, olive oil, organic bananas, spices) and the actor groups (wholesale, processor, retailer), a multi-factor analysis of variance

Table 1
The three key elements of the food fraud vulnerability assessment and the 50 associated fraud factors.

Key element	Fraud factors
Opportunities	(1) complexity of adulteration of raw materials; (2) availability technology and knowledge to adulterate raw materials; (3) fraud detectability in raw materials; (4) availability technology and knowledge to adulterate final products; (5) fraud detectability in final products; (6) complexity of counterfeiting; (7) detectability of counterfeiting; (8) access to production lines/processing activities; (9) transparency in the chain network; (10) historical evidence of fraud in raw materials; (11) historical evidence of fraud in final products.
Motivations	(12) supply and pricing raw materials; (13) valuable components or attributes; (14) economic health own company; (15) organizational strategy own company; (16) ethical business culture own company; (17) criminal offences own company; (18) corruption level country own company; (19) financial strains supplier; (20) economic health supplier; (21) organizational strategy supplier; (22) ethical business culture supplier; (23) criminal offences supplier; (24) victimization of supplier; (25) corruption level country supplier; (26) economic health sector; (27) criminal offences customer; (28) ethical business culture branch of industry; (29) historical evidence branch of industry; (30) level of competition branch of industry; (31) price asymmetries
Control measures	(32) fraud monitoring system raw materials; (33) verification of fraud monitoring system raw materials; (34) fraud monitoring system final products; (35) verification of fraud monitoring system final products; (36) information system own company; (37) tracking and tracing system own company; (38) integrity screening own employees; (39) ethical code of conduct own company; (40) whistle blowing own company; (41) contractual requirements supplier; (42) fraud monitoring system supplier; (43) information system supplier; (44) tracking and tracing system supplier; (45) social control chain network; (46) fraud control industry; (47) national food policy; (48) law enforcement local chain; (49) law enforcement chain network; (50) contingency plan

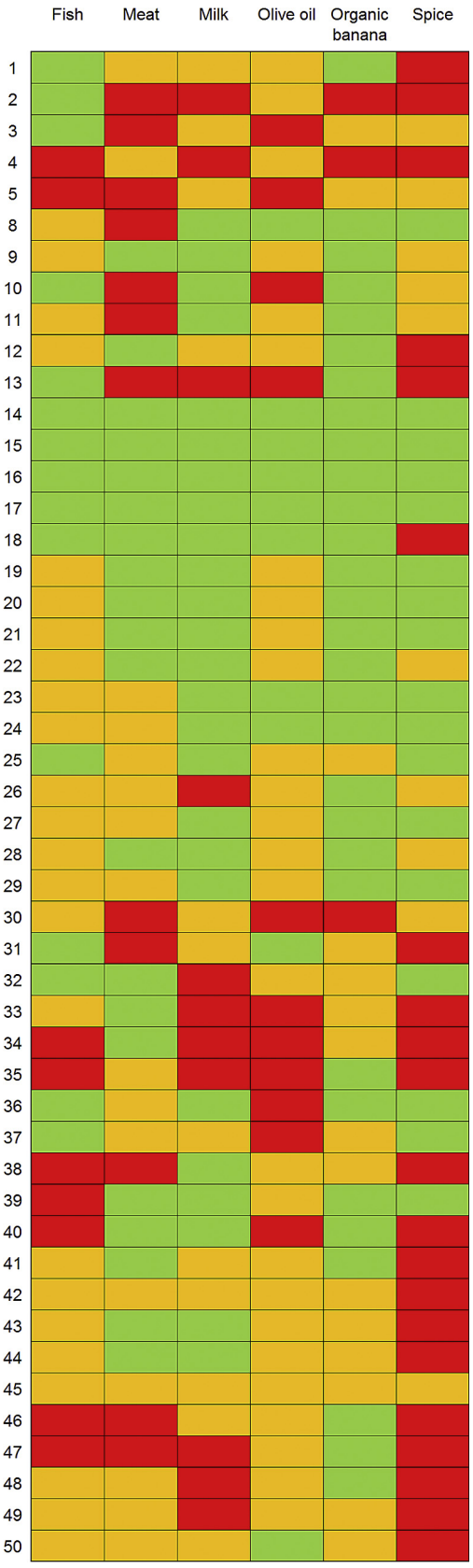

Fig. 1. Tiling-like visualisation of the most frequently recorded FFVA scores (modes) for each fraud factor across six commodity supply chains. Modes associated with high vulnerability are coloured red, with medium vulnerability orange, and with low vulnerability green.

(ANOVA; chain x actor) was carried out with subsequent post-hoc tests (Fisher's Least Significant difference tests: Fisher's LSD test). XLstat (Addinsoft, New York, NY, USA) was used for all statistical analyses and $P = 0.05$ throughout the study.

3. Results and discussion

3.1. Food vulnerability data: general results

Fraud vulnerabilities were assessed in the fish, meat, milk, olive oil, organic banana, and spice supply chains consulting the actor groups wholesalers, processors, and retailers, which resulted in scores for fifty questions for each business interviewed. Fig. 1 shows the most frequently selected vulnerability levels per question (the mode), which allows a first view of the differences and similarities across the commodity supply chains. A green box refers to a low vulnerability mode, orange to a medium vulnerability mode, and red to high vulnerability mode. It appears that generally scores for opportunities are higher than scores for motivations, whereas we notice that control measures vary across commodity supply chains. Since the motivations questions touch on sensitivities with regard to a potential offender, they may be answered slightly more reservedly than the opportunities related questions. Furthermore, a number of the motivations questions concern the own company, which may be an even more sensitive topic. This would be in agreement with the 'alien conspiracy theory' which describes that crime is often perceived as not being part of the own direct environment and shaped by the environmental circle itself, but rather a problem of threatening external parties (Kleemans, 2013). To circumvent this aspect the statistics applied involve relative comparisons.

Some general prime fraud drivers and enablers can be distinguished by selection of those fraud factors that were assigned scores above average of the respective opportunities or motivations group. These 13 factors are: (Q2/4) availability technology and knowledge to adulterate raw materials/final products; (Q3/5) fraud detectability in raw materials/final products; (Q10/11/29) historical evidence of fraud in raw materials/final products/branch of industry; (Q12) supply and pricing of raw materials; (Q13) valuable components or attributes of raw materials; (Q25) corruption level country supplier; (Q26) economic conditions branch of industry; (Q30) level of competition branch of industry; and (Q31) price asymmetries. In this group of prime drivers and enablers both opportunities and motivations related fraud factors are included, which underlines that both opportunities and motivations need to be considered. It underpins the fraud vulnerability concept which considers the elements opportunities, motivations, and (the lack of) control measures the key ingredients of food fraud. The results are also confirm statements of Moyer et al. (2017), who concluded that both macro- and micro-level factors must be considered simultaneously to assess fraud vulnerability.

Regarding mitigation of fraud by individual businesses, two options exist. One can avoid vulnerability by reducing opportunities and motivations, i.e. ceasing or not commencing activity to remove the source. Alternatively, the vulnerability can be lowered by implementation of control measures (Manning & Soon, 2016). The control measures are evaluated slightly different from the opportunities and motivations since they are not directly drivers and enablers. However, from the assessment we can determine which control measures are generally available and thus reduce vulnerability since a high and medium vulnerability scores reflect adequately and partly implemented control measures. When looking more in detail into the control measures which counteract the opportunities and motivations, it appeared that ~70% of all the businesses interviewed had any form of a fraud monitoring system

for raw materials in place, but only ~45% had a similar system for final products. Furthermore, businesses answered that ~75% of their suppliers had such a monitoring system in place. From the businesses ~30% and from their suppliers only ~10% had an elaborate fraud monitoring system in place, i.e. a systematic, evidence-based (using both historical and scientific data) sampling plan for fraud-related analyses, specific fraud screening methods and systematic use of fit-for-purpose confirmatory techniques (in house or in collaboration with accredited laboratories), customized procedures for fraud monitoring and handling of non-conformities, and systematic record keeping and detailed documentation of fraud monitoring procedures & systems (SSAFE, 2017). Approximately 80% of the businesses had an information (mass balance) system available, and ~75% of their suppliers. Similarly 85% had a tracking and tracing system present and 90% of their suppliers. On the contrary the managerial (soft) controls were not as widely available as the technical controls. Although ~80% had a code of conduct, only ~50% had a form of employee integrity screening, and ~65% had whistle blowing facilities. Ninety percent of the interviewed businesses indicated that there was some form of social fraud control in the supply chain, but only ~15% reported extensive social control. Fraud industry guidelines were lacking according to ~50% of the businesses. Furthermore, 45% and 65% businesses respectively, felt that the national food policy and enforcement were insufficiently covering fraud. The latter is remarkable since the European Commission (EC) has been addressing food fraud more extensively after the 2012 illegal horsemeat affair (EP, 2013). It resulted for instance in modified legislation and the EU Food Fraud Network of authorities sharing information on food fraud. Despite these efforts, many businesses still perceive food policy and enforcement with regard to food fraud in its infancy though.

3.2. Food vulnerability data: exploring clusters

To explore the data of the individual businesses, all FFVA data were subjected to MCA, the first two dimensions of which are plotted in Fig. 2. We see a clear grouping of actors in the same commodity supply chain. The milk and bananas (right hand side) chains are separated from the fish and olive oil chains (left hand side) in the first dimension. The spices and meat chains separate in the second dimension. The plots show that the general FFVA patterns are very much determined by the type of commodity chain.

The (dis)similarity between the chain actors interviewed was further examined by AHC (Fig. 3). We can distinguish three main clusters. One group (blue) shows generally relatively low scores for opportunities and motivations, and high scores for control measures. This low vulnerability, blue group mainly consists of fish chain and organic banana chain actors. The remainder of the businesses are clustered in two groups. Both show relatively high scores for opportunities and motivations related fraud factors. However, the red group (predominantly meat) shows high scores for control measures and thus has counteract measures in place, whereas for the green coloured group (predominantly fish, olive oil, spice) generally lower scores for control measures are observed. The AHC results are in line with the MCA results, which also showed the commodity chain groupings and associated fraud factors (Fig. 2: scores and loadings plot). The assignment to the clusters is not fully according to commodity chain though; some businesses end up in other groups than their chain counterparts. Obviously, assessment patterns are not only determined by the commodity supply chain. Therefore, we will examine the impact of the supply chain and the actor group on individual fraud factors in greater detail in the following sections.

3.3. Differences across commodity chains

The impact of the commodity chain as well as actor groups of the present study was examined simultaneously using a multifactor ANOVA. The results are presented in Table 2, which shows the 23 fraud factors presenting significant differences in scores across the commodity chains. Four opportunities related fraud factors (Q8/9/10/11, see Tables 1 and 2), nine motivations related fraud factors (Q13/18/19/22/23/24/25/27/28), and ten control measures related fraud factors (Q34/35/36/39/41/42/43/47/48/49) revealed significant differences across the commodity supply chains. Thus, the scores of about half (46%) of the fraud factors

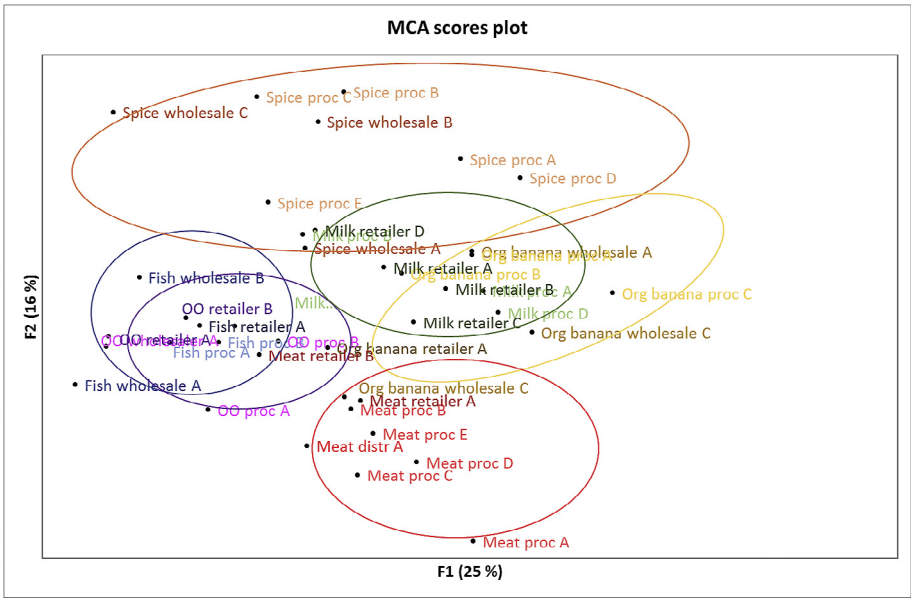

Fig. 2a. First two dimensions of a Multiple Correspondence Analysis (MCA) on all FFVA scores: scores plot (upper) and loadings plot (lower). In the upper plot colours indicate different commodities.

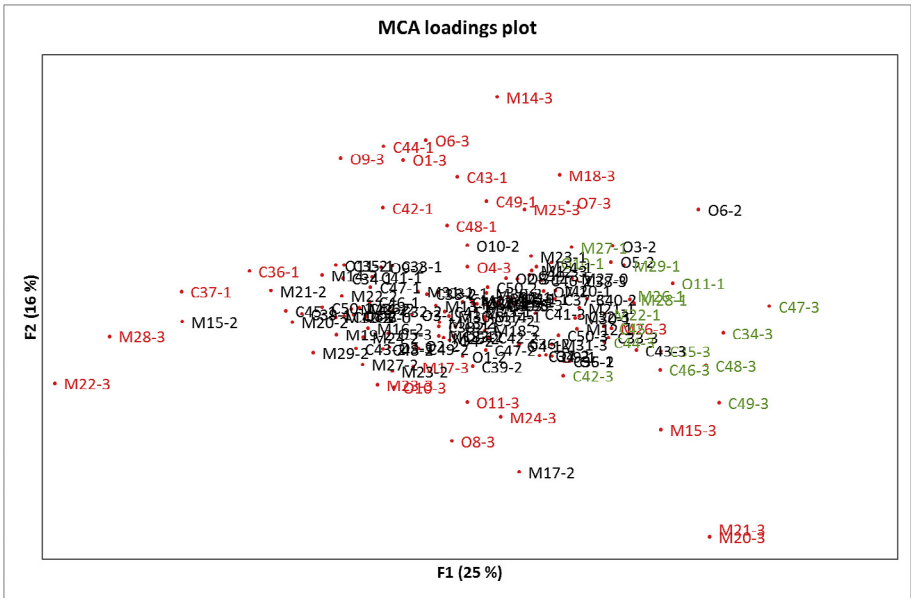

Fig. 2b. In the lower plot high vulnerability scores are coloured red, medium vulnerability scores black, and low vulnerability scores green.

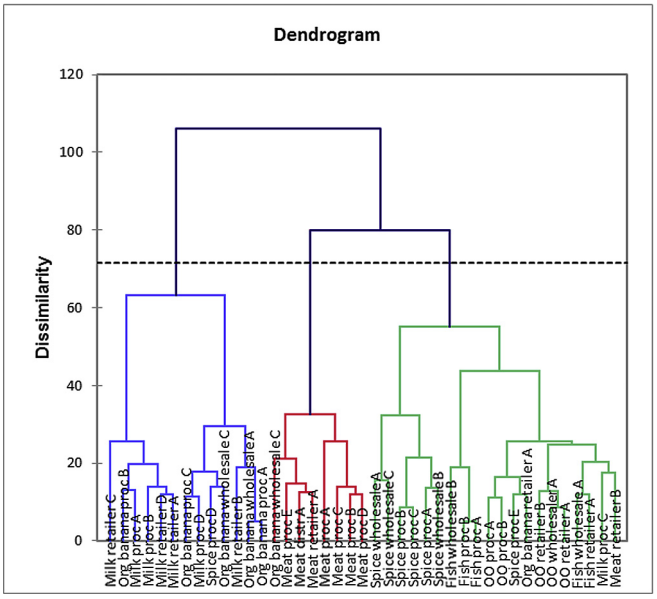

Fig. 3. Dendrogram of the agglomerative hierarchical clustering (AHC) of all FFVA scores showing the three main clusters in blue, red, and green.

contributing to fraud vulnerability appear to be significantly influenced by the commodity chain. Meat shows highest scores for opportunities related fraud factors, such as access to production lines and historical evidence (Q8/10/11). Meat and olive oil show highest scores for motivations related questions, such as valuable components and criminal offences of customers (Q13/27). On the other hand, the fish and spice chains show greatest lack of (adequate) control measures, e.g. for the availability of a fraud monitoring system for the final products and fraud preventing contractual requirements of suppliers (Q34/41). Taking all of the above into account, the order in fraud vulnerability from low to high in the current study is organic banana, milk, fish, meat, olive oil, with spice ranking highest. Although the chains were selected based on their fraud reports, it appears that we can adequately characterize and distinguish them by the fraud factors contributing to their overall fraud vulnerability. The above is in agreement with criminological research, which consistently has shown that some industries are more criminogenic than others and that structural characteristics are critical factors associated with white-collar offending (Simpson, 2011).

3.4. Differences across actor groups

Using multi-factor ANOVA, the significant differences across actor groups were examined simultaneously with the impact of the commodity chains (section 3.3), the results of which are presented in Table 3. Seven fraud factors (i.e. one out of seven) showed significantly different scores between the actor groups: one opportunities related fraud factor (chain transparency: Q9), two motivations related fraud factor (financial strains supplier: Q19; criminal offences customer: Q27), and four control measures related fraud factors (companies' information system: Q36; and ethical code of conduct: Q39; contractual requirement suppliers: Q41; enforcement local chain: Q48). The latter are managerial control measures only. All these fraud factors are also affected by the commodity chain, so there is an effect on these scores by both the actor group and the commodity chain.

Although the three actor groups: processors, retailers and wholesalers all three rate high for one of the opportunities/motivations related questions, it is in particular the (lack of) control measures that demonstrate differences between the groups. The processors have most or most adequate control measures in place, followed by the retailers, and eventually the wholesalers group. From this perspective, the wholesalers (including wholesale, traders, distributors) are most vulnerable to fraud. Since they are in the middle of the chain, they are also more likely to pass on the potential fraud to their customers. In chains with this kind of actors, and especially with a larger number of them, e.g. such as present in the spices chain, overall fraud vulnerability is likely to be enhanced. That fraud vulnerability of actor groups vary is due to the varying modus operandi and vivendi of different groups in the supply chains. They have been described extensively for the meat supply chain in relation to fraud by Manning, Smith, and Soon (2016).

Table 2
Fraud factors of the FFVA demonstrating significantly different vulnerability across commodity supply chains.[a]

Question nr	Fraud factor	Org banana *n=8*	Milk *n=8*	Fish *n=5*	Meat *n=5*	Olive oil *n=8*	Spice *n=8*
Opp. 8	Access production lines	C	C	AB	A	BC	C
9	Transparency chain network	B	B	AB	B	B	A
10	Historical evidence raw materials	B	B	B	A	A	B
11	Historical evidence final products	D	CD	AB	A	B	BC
Motiv. 13	Valuable components/attributes	B	A	C	A	A	A
18	Corruption level country own company	B	B	B	B	B	A
19	Financial strains supplier	B	AB	AB	B	A	B
22	Ethical business culture supplier	C	C	AB	BC	AB	AB
23	Criminal offences supplier	B	B	AB	A	B	B
24	Victimization supplier	BC	BC	AB	A	BC	C
25	Corruption level country supplier	A	C	C	BC	AB	AB
27	Criminal offences customer	B	B	AB	A	A	B
28	Ethical business culture industry	C	BC	AB	C	A	ABC
Controls 34	Fraud monitoring system final products	A	BC	C	AB	BC	C
35	Verification system Q34	A	B	B	A	B	B
36	Information system own company	A	AB	AB	AB	B	AB
39	Ethical code of conduct own company	A	AB	B	AB	AB	A
41	Contractual requirements supplier	B	AB	B	A	AB	B
42	Fraud monitoring system supplier	A	AB	AB	A	AB	B
43	Information system supplier	AB	A	B	AB	B	C
47	National food policy	A	AB	B	AB	AB	B
48	Law enforcement local chain	A	A	AB	A	A	B
49	Law enforcement chain network	AB	BC	AB	A	AB	C
Overall vulnerability							

[a] Different capital letters in a row indicate significant differences (Fisher's LSD test, $P < 0.05$); Higher, intermediate, and lower vulnerability scores are coloured red, orange, and green, respectively

Table 3
Fraud factors of the FFVA demonstrating significantly different vulnerability across actor groups in supply chains.[a]

Question nr	Fraud factor	Processor *n=22*	Retailer *n=13*	Wholesale *n=7*
Opp. 9	Transparency chain network	B	AB	A
Motiv. 19	Financial strains supplier	B	A	AB
27	Criminal offences customer	A	AB	AB
Controls 36	Information system own company	A	B	B
39	Ethical code of conduct own company	A	A	B
41	Contractual requirements supplier	AB	A	B
48	Law enforcement local chain	A	B	A
Overall vulnerability				

[a] Different capital letters in a row indicate significant differences (Fisher's LSD test, $P < 0.05$); Higher, intermediate, and lower vulnerability scores are coloured red, orange, and green, respectively

4. Conclusions

This study provided insight in prime fraud drivers and enablers, used counteracting control measures, and the relative fraud vulnerabilities of six commodity supply chains and their actors. We identified 13 prime fraud drivers and enhablers (opportunities and motivations related fraud factors) which seem to contribute highly to the fraud vulnerability of the assessed chain actors. The control measures vary a lot across supply chains and actor groups. Often technical control measures (hard controls) are to some extent in place, but managerial (soft) controls which counteract motivations-related fraud factors are less extensively present. Managerial controls at the wider environment level, i.e. social control and food policy and enforcement, are perceived as lacking or insufficient in many cases.

Fraud vulnerability was shown to be determined by both the commodity chain and the position of the actor in that chain: ca. half of the fraud factors were significantly impacted by the type of commodity chain and one out of seven of the fraud factors by the actor group. Based on differences and similarities between the chains and actor groups, we demonstrated that the spices chain ranked highest in overall fraud vulnerability; subsequently followed by olive oil, meat, fish, milk, and organic banana. The wholesalers/traders group is considered as most vulnerable among the actor groups, they were followed by the retailers, and processors groups.

The current study provided understanding of the fraud vulnerability and associated fraud factors in six supply chains. In future work, it is of interest to compare data with chains with a relatively low number of fraud reports and composite food products. Furthermore, an extension of the individual supply chains examined would increase insight as well and could involve fraud vulnerability examinations of primary producers, as well as food service and catering actors.

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