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Knowledge, Attitude, and Practices of Swine Farmers related to Livestock Biosecurity: A Case Study of African Swine Fever in Vietnam

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ABSTRACT

Purpose: *African Swine Fever (ASF), one of the world's most contagious and deadly livestock infectious diseases, was introduced to Vietnam in 2019 and has since become one of the biggest threats to the country's porcine industry. To this day, very little is known about the major drivers of ASF outbreaks – in particular, the generally low levels of biosecurity found on smallholder farms in Vietnam. The main objective of this paper is to assess the knowledge disparities, diverging attitudes, and different practices among smallholder pig farming households that influence the adoption, implementation, and continuation of ASF biosecurity measures in Vietnam.*

Research Method: *Structured questionnaire surveys were conducted to 183 smallholder pig farming households in December 2020 in four districts of Dong Nai, the largest pig production province in Vietnam. The determinants of farmers' knowledge and attitude toward ASF were estimated using an ordinal probit regression; a panel-data probit regression approximated the probability of farmers adopting biosecurity measures.*

Findings: *It was found that, prior to the first outbreaks of ASF in Vietnam in 2019, surveyed pig farmers generally had an inadequate level of knowledge about ASF to be able to successfully prevent and control the disease's spread. Rather, farmers only managed to significantly improve their understanding of ASF after outbreaks had begun. Model estimates indicate that a better understanding of ASF ultimately helped improve farmers' attitudes toward ASF biosecurity measures. Additionally, farmers with previous experience in dealing with other livestock infectious disease outbreaks were, in most cases, found to be more willing to implement ASF biosecurity measures. Together, deeper understanding of ASF and more positive attitudes towards ASF prevention and control measures contributed to an overall increase in the likelihood of farmers adopting and implementing appropriate ASF biosecurity practices.*

Originality/ Value: *This paper highlights the need for improved community education campaigns in efforts to prevent and contain ASF outbreaks, as well as the need for increased financial assistance and support for swine farmers to enable them to adopt effective biosecurity practices.*

Keywords: *African Swine Fever, attitude, biosecurity, knowledge, practices, Vietnam*

INTRODUCTION

In 2019, African Swine Fever (ASF) became the latest infectious swine disease to devastate Vietnam's porcine industry. ASF is a transboundary viral disease which affects both wild and domesticated pig populations (World Organisation for Animal Health, 2021). In addition to being extremely contagious and

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resistant to environmental change, acute forms of ASF are particularly deadly: mortality rates can reach between 90 and 100% (Beltran-Alcrudo *et al.*, 2017) and there is to this day still no vaccine against the disease. Though Vietnam successfully managed to develop a first home-produced vaccine against ASF in June 2020, the government temporarily halted the inoculation campaign in late August 2022 after dozens of vaccinated pigs died, a suspension still in place as of September 2022 (Toan, 2022; Vu, 2022). ASF is therefore a serious threat to the world's swine industry, especially in countries where there are insufficiently effective import regulations and measures in place to prevent and control outbreaks, such as in Vietnam (Penrith, 2009).

Pig farming is the dominant sector of Vietnam's livestock industry (General Statistics Office of Viet Nam, 2021). In 2000, pigs accounted for nearly 74% of the total output of the country's livestock industry; pork is also the most consumed type of meat by the Vietnamese, accounting for 52.6% of the country's total amount of consumed meat (Van Phuong *et al.*, 2014). From 2006 to 2020, the nation's total swine population decreased from approximately 27 million to 22 million pigs, a fact attributed to the ravages by various porcine infectious diseases, including ASF, and product price volatility. The cumulative financial cost of porcine infectious diseases in recent years is estimated at more than 64 million United States Dollars (USD) (Foot-and-Mouth Disease, 2006-2010) and 72 million USD (Porcine Reproductive and Respiratory Syndrome, 2007-2010) (McLeod *et al.*, 2013).

In February 2019, the first outbreak of ASF in Vietnam was reported from Hung Yen province (Le *et al.*, 2019). Since then, cases of ASF have been registered in every one of the country's 63 provinces, with approximately 6 million pigs culled from 2019 to 2020 (Lee *et al.*, 2021a). From August 1, 2018, to December 31, 2019, Vietnam recorded the highest number of ASF outbreaks (186 reports) among all countries in Asia (Mighell and Ward, 2021). Moreover, ASF has shown trends of reoccurrence in several localities; in 106 communes distributed across 23 provinces, new outbreaks were reported more than 30 days following the original outbreaks (Hau, 2019).

Among livestock infectious disease found in Vietnam, ASF is by far the most lethal and the hardest one to prevent and control. Confirmed cases in the country were mostly found on smallholder farms and had severe impacts on farmers' livelihoods; disease prevention and outbreak control costs were substantial, exceeding the budgets of local authorities. An estimate of damages due to ASF-related pig culling was numbered to be between 880 million and 4.4 billion USD (Nguyen-Thi *et al.*, 2021).

Currently, the implementation of appropriate biosecurity measures remains the most effective method for pig holdings to prevent and control ASF outbreaks (Jiang *et al.*, 2022). Nevertheless, despite efforts by the Vietnamese Ministry of Agriculture and Rural Development (national level) and the Department of Agriculture and Rural Development (provincial level) since November 2018 to encourage swine farmers to preemptively prepare their farms for outbreaks with appropriate biosecurity measures (MARD, 2018), ASF managed to quickly spread throughout Vietnam in 2019 (Mighell and Ward, 2021).

One area that was particularly hard-hit by cases of ASF in 2019 was Dong Nai, the largest swine production province of Vietnam; it accounted for 8% of the country's total pig population in 2020 (General Statistics Office of Viet Nam, 2021). The wave of ASF outbreaks in 2019 had devastating impacts on the province's swine production industry; from April to December 2019, 5371 pig farms across 81 communes from all 11 districts of the province reported outbreaks of ASF, with approximately 450,000 pigs being culled as a result. A particular characteristic of the surge of ASF outbreaks in Dong Nai is the rapid rate of outbreak occurrence during the month of July 2019, when 644 households reported outbreaks, leading to over 57,300 pigs being culled (Tri, 2020).

In this context, what, then, explains the occurrence of ASF outbreaks in Vietnam despite concerted efforts to prevent and contain the disease's spread? It is suggested that the rapid rise in outbreaks can be partly explained by the fact that most swine production in Vietnam is from smallholder farms (Nguyen-Thi *et al.*, 2021), which are reputed to having low biosecurity levels (Baudon *et al.*, 2017). These types of farms play an important role in the commercial movements of pigs, which is recognized as a leading driver of disease transmission (Kamakawa *et al.*, 2006). On this basis, this paper addresses the following research question: What underlying factors negatively influence the adoption, implementation, and continuation of ASF biosecurity measures among smallholder swine farmers in Vietnam?

The bulk of international studies on ASF have globally focused on economic impact analyses of ASF on the agricultural sector (Swai and Lyimo, 2014; Smith *et al.*, 2019; Tian and von Cramon-Taubadel, 2020), as well as on porcine product transportation routes and infection risks (Vergne *et al.*, 2017a; Vergne *et al.*, 2017b; Sur, 2019; Ito *et al.*, 2019; Jurado *et al.*, 2019).

In Vietnam, recent studies about ASF have largely focused on the genetic characterization, variants, and pathogenicity of the ASF virus circulating in the country (Mai *et al.*, 2021; Tran *et al.*, 2021; Lee *et al.*, 2021b; Izzati *et al.*, 2021; Nguyen *et al.*, 2022). Several studies have also been done on the disease's transmission pathways and spatiotemporal spread (Mai *et al.*, 2022; Le *et al.*, 2019; Shao *et al.*, 2022; Lee *et al.*, 2021c).

There have been just a small number of studies on ASF in Vietnam undertaken from a socioeconomic perspective. Among the notable few would be the assessment of pig farmers' perceptions toward ASF in Tra Vinh province, by Qui *et al.* (2021). To this can be added the work of Nguyen-Thi *et al.* (2021) describing the adverse economic impacts of ASF on the sector level and the national level of the swine industry in Vietnam. Very little remains known on the underlying determinants of poor adoption rates of proposed ASF biosecurity measures among smallholder swine farmers in Vietnam.

According to the World Health Organization (WHO, 2008), it is crucial to determine knowledge gaps, cultural beliefs, and human behaviors that can hinder infectious disease prevention and control efforts. As such, positive behaviors of farmers towards livestock infectious disease biosecurity measures are critical for limiting the spread of ASF (Penrith *et al.*, 2013).

Very humbly contributing to the existing body of literature on ASF from a socioeconomic standpoint, the purpose of this paper is to assess the knowledge disparities and behaviors among smallholder swine farmers that impede the widespread adoption, implementation, and continuation of ASF biosecurity measures in Vietnam. To this end, the specific objectives are to identify and analyze, in the context of Dong Nai province: 1) the drivers of ASF outbreaks, and 2) the underlying determinants influencing swine farmers' decision to not adopt/continue implementing recommended ASF biosecurity measures.

MATERIALS AND METHODS

The Knowledge, Attitudes, and Practices Framework

A widely used method to determine factors impeding infectious disease prevention and control efforts is the Knowledge, Attitudes, and Practices (KAP) framework. This analysis tool is commonly used to assess a population's familiarity, beliefs, and actions pertaining to a particular issue (WHO, 2008). Specifically, KAP analyses can identify three types of information (Tiongco *et al.*, 2012): "Knowledge (the degree of actual understanding of the topic and associated issues), Attitudes (feelings toward the subject, including the judgment of its importance and influence on people's lives), and Practices (actions taken as a result of the knowledge, attitude toward the issues).".

In the context of livestock disease prevention and control, KAP analyses are commonly applied to assess how successful livestock disease educational campaigns are in disseminating information to the general public or a target population. The findings of such analyses are key to verifying whether livestock producers and consumers are sufficiently knowledgeable of a disease and its risks, a crucial basis from which appropriate precautionary measures can be taken to prevent and control outbreaks (Tiongco *et al.*, 2012).

Among known infectious livestock diseases, there exist several analyses of KAP toward the Pathogenic Avian Influenza (HPAI) – commonly known as the 'avian/bird flu' – in Asia. In Thailand, for example, there have been notable analyses of the country's rural population's KAP toward HPAI that correlated attendance to educational campaigns with improved knowledge on the disease's transmission cycle, though ultimately it was found that peoples' behaviors and practices toward poultry generally did not adjust accordingly (Olsen *et al.*, 2005; Suphunnakul and Maton, 2009). Similarly, this time in the urban setting of Hong Kong, research findings from (Fielding *et al.*, 2005; Di Giuseppe *et al.*, 2008) showed how educational campaigns on HPAI were able to sufficiency influence residents into adopting low-risk behaviors toward poultry, though only on a temporary basis; initial (high-risk) behaviors and practices would generally reappear. Such studies raise an important issue facing public educational campaigns on livestock diseases: Regardless of any short-term success, educational campaigns can be nullified in the long-term if some people are unwilling to, or incapable of, adjusting their attitudes and practices toward livestock and its products.

In Africa, there are studies on KAP analyses showing how socioeconomic factors can play an important role in determining whether a population is capable of acting upon recommended prevention and control actions for livestock infectious diseases. A key finding from an analysis of KAP among smallholder poultry farmers toward HPAI in Kenya is that a significant correlation can be made between adopting biosecurity measures and the level of household income; households with lower levels of income generally did not embrace biosecurity measures proposed by the government (Tiongco *et al.*, 2012). Likewise, a study in Uganda describes how actors involved in the swine supply chain were largely constrained by the local context of widespread poverty in their attempts to implement ASF control measures, despite having a deep understanding of the disease and its risks (Chenais *et al.*, 2017).

The use of the KAP framework in different geographical contexts underlines the limitations of educational campaigns on livestock infectious diseases and a need for greater consideration of socioeconomic conditions when developing strategies designed to boost biosecurity adoption levels.

Study Sites

Data was collected from four districts of Dong Nai, the largest pig producing province in Vietnam. The selected districts are Thong Nhat, Trang Bom, Vinh Cuu, and Cam My (Figure 01); 49.8% of Dong Nai's total pig population is found in these four districts (Dong Nai Department of Statistic, 2018).

Data Collection

Primary or direct data collection was preferred to secondary data collection in this study to allow for a methodical and cohesive analysis of data relevant to meeting research objectives. This study employed individual interviews to collect primary data from a sample of pig farming households in Dong Nai province during the month of December 2020. The minimal sample size for analyses was 138, determined by using the formula of Tabachnick *et al.* (2007), wherein is the sample size and is the number of explanatory variables in the regression model.

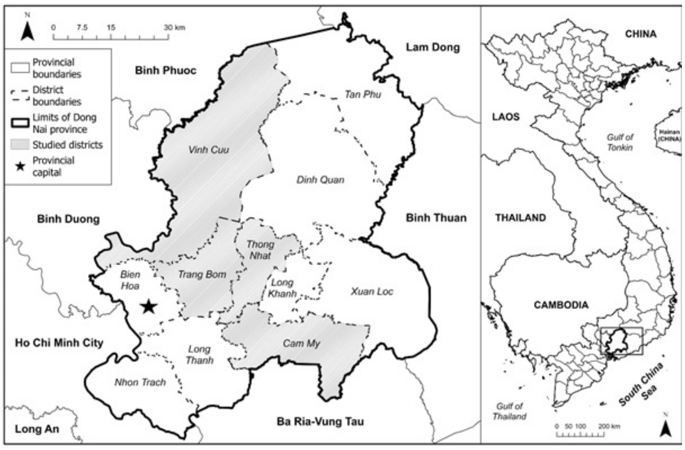

Figure 01: Studied districts in Dong Nai province, Vietnam

Spatial data sources: (GADM, 2022; DIVA-GIS, 2022); Note: Map made by Antoine Beaulieu (2022).

In total, 200 in-person interviews with heads of households were conducted. Prior to the beginning of interviews, informed consent was obtained verbally from each research participant. Since the onset of outbreaks of ASF in Vietnam, swine farmers are generally very careful to avoid any potential risk of disease transmission from outsiders, making it very difficult to approach them for research purposes without the proper introduction and/or guidance from local authorities. Thus, the non-probability convenience sampling method was used to select interviewees in the study sites.

After the investigation and data screening processes were completed, 183 responses were retained and 17 were disqualified. A structured questionnaire was used to gather data on household demographics (e.g., household size, gender, and education level) and socio-economic information, such as details on pig production (breeding, feeding and management practices, production scale), farmers' experience in dealing with other infectious swine diseases (FMD and PRRS), and finally the KAP of farmers toward ASF. Questions about ASF clinical symptoms, characteristics, transmission routes, and biosecurity measures were referenced from guidelines by the Food and Agriculture Organization of the United Nations (FAO) on developing surveys for ASF detection and diagnosis (Beltran-Alcrudo *et al.*, 2017), as well as from participatory rural appraisals by Chenais *et al.* (2017). Additionally, in-person key informant interviews were conducted with 6 employees form the Department of Agriculture and Rural Development at the district level. All key informants were recruited based on their knowledge of the situation regarding ASF outbreaks in their respective district issues. Informed consent was obtained verbally from all key informants prior to the beginning of interviews. T-tests and ANOVA were conducted in SPSS to identify any significant differences in the dataset.

Data Analysis

The present approach to analyze Vietnamese swine farmers' KAP related to ASF is based on the procedure used by Tiongco *et al.* (2012). This study's analysis of KAP includes two phases: 1) the development of indices of knowledge and attitudes toward ASF, and 2) the identification of variables that can influence an individual's KAP.

For the first phase, a knowledge index was developed to identify farmers' overall level of knowledge of ASF's four characteristics and ten clinical symptoms, as listed by the FAO (Beltran-Alcrudo *et al.*, 2017). Interview participants were asked to name as many of these characteristics and symptoms as they could. Each correct answer was assigned 1 point, while wrong answers got 0 points; scores were subsequently summed to provide the knowledge index of a pig farming household. The index ranges from 0 to 14. For the attitude index, a 5-point Likert scale was used to determine pig farmers' level of concern toward ASF in the event of an outbreak in their community. The attitude index took the value of 1 when a farmer was the least concerned and 5 when the farmer was the most concerned.

In the second phase, multivariate regression analyses of KAP indices were conducted. Firstly, the variables that can influence a person's knowledge of ASF were identified. A first regression model was subsequently calculated, wherein the Knowledge index is a function of several explanatory variables:

$$Knowledge\ index_i = \beta_i x_i + u_i \qquad i=1\ldots,\ n \quad (1)$$

Here, *knowledge index*$_i$ is the knowledge index of the household$_i$ while represents explanatory variables of household$_i$ (Table 01).

Past experience in dealing with livestock infectious diseases is an important variable that can affect the KAP of a farmer; households with previous experience are found to have a deeper understanding and heightened concerns regarding disease risks (Tiongco *et al.*, 2012). The work by Makita *et al.* (2020) also indicates that experience is an explanatory factor of a farmer's level of knowledge.

A set of demographic variables (pig farming experience, gender, education, and the number of household members involved in pig farming) were included in the model to allow for a comprehensive analysis of their influence on farmers' ability to deeper their understanding of ASF and adopt appropriate biosecurity measures. Such variables have previously been employed in other analyses of KAP (Leslie *et al.*, 2008; Manabe *et al.*, 2012; Chenais *et al.*, 2017), as they can prove useful to identify, for example, any potential differences in responses between male and female household heads, as well as verify if deeper understanding and good practices toward a disease correlate with higher education levels, and whether the number of swine farmers in a household can positively contribute to the household's KAP toward ASF.

On the basis that the production scale and the importance of pig farming to households' livelihoods can significantly affect farmers' behaviors, another set of variables, this time pertaining to household pig production, was included in the model: This group of variables includes the total farm area, the pig herd size, the distance to the nearest farm, and the earnings from pig production. Comparable variables can be found in the studies by Tiongco *et al.* (2012) and by Makita *et al.* (2020).

Table 01: Variables in the regression models.

Variables	Explanation
Prob.implementation$_{ik}$	The probability of implementing biosecurity measure *k* of the household *i* (1: implemented, 0: not implemented)
Knowledge index$_i$	The knowledge index of the household *i* (0-14)
Attitude index$_i$	The attitude index of the household *i* (1-5)
X_1	Household head experience in dealing with previous infectious swine diseases (1: yes, 0: no)
X_2	Gender of the household head (1: male, 0: female)
X_3	Household head experience in pig farming (number of years)
X_4	The education level of the household head (number of schooling years)
X_5	The number of household members involved in pig farming in in 2019 (number of people)
X_6	The distance from the household's farm to the nearest farm in 2019 (km)
X_7	The total area of the farm in 2019 (ha)
X_8	The herd size of the household in 2019 (number of pigs)
X_9	Total household income from pig farming in 2019 (billion VND)

Secondly, the determinants of farmers' attitudes toward ASF were identified. A second regression model was developed according to the hypothesis that a farmer's level of knowledge of ASF can influence his/her attitude toward the disease (cf. studies on peoples' KAP toward Avian Influenza in Thailand (Olsen *et al.*, 2005) and in Italy (Di Giuseppe *et al.*, 2008). As such, the knowledge index serves as an explanatory variable in the second regression model:

$$Attitude\ index_i = \beta_1\ knowledge\ index_i + \beta_i\ x_i + u_i$$

$$i=1\ldots,\ n \quad (2)$$

Wherein *Attitude index$_i$* is the attitude index of household$_i$, *Attitude index$_i$* is the knowledge index of household$_i$, while x_i represents explanatory variables (Table 01). The first and second equation applied ordered probit regression, a suitable method for statistical analysis every time the ordinal dependent variable has more than two outcomes (Winship and Mare, 1984).

In the third estimation, the determinants of biosecurity measures adopted by farmers were assessed. Specifically, it was expected to identify the factors influencing the probability (yes/no) that farmers implemented biosecurity measures for ASF. Each farmer had different probabilities for every one of the surveyed biosecurity measures. Therefore, a panel-data probit model was employed. Two KAP indices (knowledge index and attitude index) served as explanatory variables to examine how knowledge and attitude influenced the probability of adopting ASF biosecurity measures. The model for measuring the probability of adopting biosecurity measures k (k = 1, 2,…, ni) of a household i (i = 1, 2,…, N) is:

$$Prob.implementation_{ik} = \beta_1\ knowledge\ index_i + \beta_2\ Attitude\ index_i + \beta_i\ x_{ik} + \epsilon_{ik} + u_i \quad (3)$$

Where *Prob.implementation$_{ik}$* is the probability of household$_i$ adopting biosecurity measures$_k$, x_{ik} is a vector of data, β is a vector of coefficients, ϵ_{ik} is an i.i.d (independent and identically distributed) idiosyncratic error term, and u_i is the mean-zero error term of household$_i$ (Bland and Cook, 2019). The coefficient α_i explains the deviation of household$_i$ from the overall population mean (Gibbons and Hedeker, 1994). The panel data probit model was estimated using the Generalized Estimating Equations method.

RESULTS AND DISCUSSION

Characteristics of Surveyed Households

The average years of experience in pig farming among the surveyed households was 12 years, with the most experience being 47 years and the least being two years. Therefore, all households were breeding pigs when ASF emerged in 2019 in Vietnam. Swine farmers in Thong Nhat, Cam My, and Trang Bom had similar years of experience on average, respectively 14, 13, and 11 years. Interviewed farmers in Vinh Cuu district were generally less experienced, with an average experience of 6 years.

In 2019, surveyed households' average cost in pig production was 22,491 USD, which yielded a net return of 7938 USD. However, not all of the farms profited from swine production in 2019. Because of ASF outbreaks, 23% of households suffered financial losses. The worst-hit household saw 1200 infected pigs culled, with financial losses amounting to 88,202 USD. The production performance was different across districts. As the most important pig production district in Dong Nai, the net return of production was highest in Thong Nhat (10,706 USD/household. In second place is Cam My, with 6791 USD/household. Profit in Trang Bom and Vinh Cuu was significantly lower at 2557 USD and 2469 USD/household, respectively. The difference in profit among the districts can be attributed to the production scale of surveyed households.

According to the classification of livestock establishments in Clause 2, Article 21 of Decree No. 13/2020/ND-CP (Government of Vietnam, 2020), which includes micro-sized farms (less than 10 pigs), small-sized farms (between 10 and 30 pigs), medium-sized farms (between 30 and 300 pigs), and large-sized farms (over 300 pigs), most surveyed households had medium-sized farms (65%), while 23.5% had large-scale farms. Among all studied districts, there was a significant difference in households' pig herd size (Table 02). More than 90% of ASF outbreaks in Vietnam were found on small and medium-sized farms with poor levels of biosecurity implementation (Nguyen-Thi *et al.*, 2021; Shao *et al.*, 2022).

The largest swine production scale was recorded in Thong Nhat district, where up to 31.4% of farms were large-sized; on average, each farm raised 293 pigs. Meanwhile, pig production in Vinh Cuu was smaller than that of the other studied districts in both herd size and in farm area, leading to lower economies of scale.

The average total area of all surveyed pig farms was 0.041 ha, with the smallest area recorded at 0.002 ha and the largest numbering 0.6 ha. The total farm area was positively correlated with the herd size, which varied from less than 30 pigs in small-sized farms to over 1000 pigs in large-sized farms. It was found that 85% of all surveyed farms still used traditional open pens with simple structures (e.g., concrete floors, corrugated iron roofs, brick walls no more than 80 centimeters in height), as opposed to around 15% of farms that have modern closed pens with more advanced structures (e.g., water cooling systems, exhaust fans, automatic temperature control systems). Such findings indicate an unwillingness and/or inability by most farmers to invest large amounts of money needed to convert into/build new closed pens.

Among 183 surveyed farms, 136 (73.4%) reported to have detected ASF infected pigs over the course of 2019 **(**Table 03).

Table 02: Vietnam, Dong Nai province, selected districts, pig herd size, production scale, and farm size of surveyed pig farming households, 2019.

			Cam My	Thong Nhat	Trang Bom	Vinh Cuu	Total sample
Pig herd size		Mean	254_a	293_b	146_c	36_d	235
Farm scale	Micro	Count	5	1	0	0	6
	Small	Count	1	9	0	5	15
	Medium	Count	14	62	29	14	119
	Large	Count	7	33	3	0	43
Pig farm total area (ha)		Mean	0.058_a	0.048_b	0.022_c	0.012_c	0.04

Note: Values in the same row and sub-table not sharing the same subscript are significantly different at p< 0.05

Table 03: Vietnam, Dong Nai province, selected districts, number of farms with confirmed ASF cases, average number of infected pigs of surveyed households, farm density, 2019.

	Infected farms		Average number of infections	Farm density
	No	Yes	Infected pigs/farm	Farms/km^2
Cam My	20	7	60	0.49
Thong Nhat	14	91	160	4.46
Trang Bom	8	24	76	1.26
Vinh Cuu	5	14	22	0.06

On average, all households having experienced ASF outbreaks had a total of 116 infected pigs; the household with the largest number had 1000, while the one with smallest number had only 1. Because of the disease's extraordinarily high mortality rate, close to 98% of all infected pigs in surveyed households died. Noticeably, it was found in 11 households (10 in Thong Nhat and 1 in Trang Bom district), whose combined total number of infected pigs was 719 or 57.1% of their combined herd size, exhibited only mild symptoms of ASF and managed to eventually recover from the infection. The probability of infection was not equal spatially across studied districts. While the infection rates were above 70% in Thong Nhat, Trang Bom, and Vinh Cuu, it was just 26% in Cam My.

As the most important pig producing district of Dong Nai, Thong Nhat was the hardest hit by ASF; the number of infected pigs per farm here was more than twice as many as that of the district with the second-most number (Trang Bom). The largest single outbreak out of all surveyed households was also recorded in Thong Nhat, with 1000 infected pigs. Contrastingly, only 26% of households in Cam My reported ASF infections. Higher infection rates in some districts appear to correlate with the size of pig clusters of production facilities. For example, Thong Nhat had more than 1108 pig farms distributed over a total area of only 250 km^2.

In the first phase of ASF outbreaks in Vietnam (February 2019-August 2019), significant concentrated outbreak areas were also found in the provinces of Bac Ninh, Ha Nam, Ha Noi, Hai Phong, Hung Yen, and Thai Binh (Shao *et al.*, 2022). At the global scale, 52% of the world's swine population is being raised in ASF high-risk zones, with the majority of these zones being in Asia (Jiang *et al.*, 2022).

Farmers' Knowledge of African Swine Fever

The most common sources of information from which surveyed households learned about ASF were television, radio, friends, relatives, and local veterinary officials. Approximately 75% of interviewees correctly answered every question regarding the characteristics of ASF. Around 20% of interviewed farmers inaccurately believed that humans can be infected with ASF, while 61.2% thought that it was impossible to prevent an ASF outbreak. The latter belief is grounded on a general impression that cases of reinfection illustrate how the virus has an ability to spread and overpower what would appear to be ineffective precautionary methods used to prevent ASF outbreaks. This reasoning was summarized by one respondent:

"When ASF appeared in this district, I used every possible biosecurity method, such as disinfecting the farm and its surrounding area every day, as well as prohibiting people from entering my farm, but still my pigs were infected and culled. Then, I carefully conducted disinfection and sterilization for pig re-herding, but my herd was infected for the second time. So, I believe that this disease cannot be prevented. After the second re-herding, I only attempted to increase the resistance of my pigs through supplemental food, vitamins, and medicine."

Such a viewpoint highlights how, despite the fact that biosecurity measures remain the most effective means to prevent and control ASF outbreaks (Jiang *et al.*, 2022), there are individuals who still perceive biosecurity as being ineffective due to the difficulties in determining the transmission pathways (Blome *et al.*, 2020). Results indicate that most surveyed pig farmers in Dong Nai province knew enough about ASF to be able to recognize at least one clinical symptom of the disease (Figure 02).

Over 50% of surveyed farmers correctly detected at least 7 out of 10 of the diagnostic signs of pigs infected with ASF. Among the ten symptoms, both a high fever (40-42^{o}C) and a lack of appetite were the most accurately identified, with over 80% of surveyed farms having detected them. In contrast, only 53% of the interviewees were able to recognize increased respiratory rate and ocular and nasal discharge. Moreover, 64% of the interviewees failed to identify bloody faeces or tail as a symptom. As reflected by farmers' answers, some ASF symptoms are easily confused with those of other swine diseases, such as Salmonellosis or Swine Erysipelas. Smith *et al.* (2019) also mentioned the difficulty in distinguish ASF from Classical swine fever. Additionally, some infected pigs from five farms in Cam My district did not show any evident clinical symptoms of ASF, meaning that farmers were unaware of such infections and consequently were unable to identify many symptoms when asked. Such knowledge levels among Vietnamese farmers are comparable with those of Cameroonian farmers; in one study, 90% of interviewed farmers knew about ASF but only 36.3% were able to identify the major symptoms, with several farmers confusing symptoms of ASF with those of other swine diseases (Ngu Ngwa *et al.*, 2020). Cases of incompete understanding of ASF among swine farmers were also found in Senegal (Missohou *et al.*, 2001), the Central African Republic (Abdallah, 1997), and Madagascar (Grenier, 2005). Farmers' answers to these questions were assigned scores, which helped determine their knowledge indices (Figure 03). The average score for the total sample was 8.4, with the lowest being three and the highest twelve. The range of the knowledge index implies that not a single farmer who was able to correctly identify all clinical symptoms of ASF. The distribution of the knowledge index was concentrated in the range of seven to ten. Importantly, tests were conducted to reveal a significant difference between farms with reported ASF outbreaks and those without, as farms whose herds suffered outbreaks tended to get higher scores.

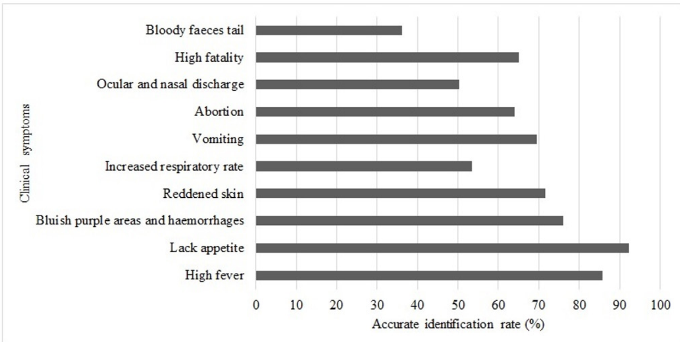

Figure 02: Vietnam, Dong Nai province, selected districts, accurate identification rate of ASF clinical symptoms by surveyed pig farmers, 2019

Note: Though technically not a clinical symptom, a high fatality rate is included here as a warning sign of ASF infections in a herd; farmers often suspected the occurrence of an ASF outbreak when several pigs from the same herd got sick around the same time and died.

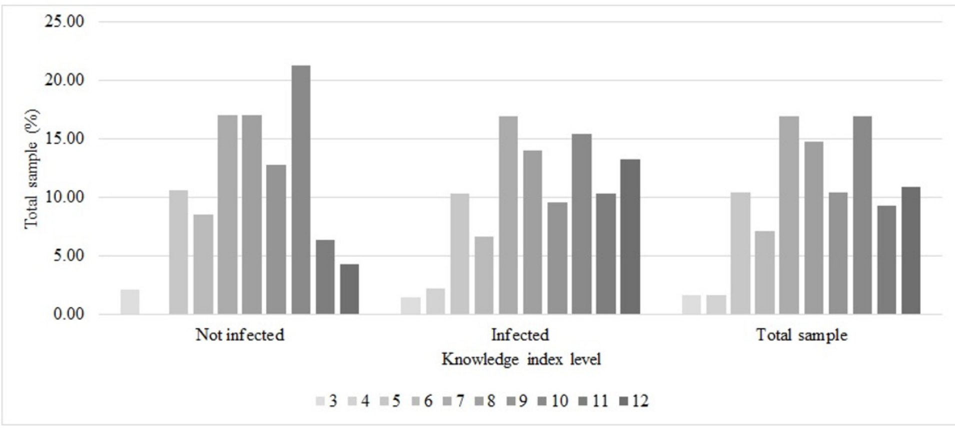

Figure 03: Vietnam, Dong Nai province, selected districts, distribution of knowledge indices toward ASF, 2019

The estimated result of the first ordered probit model revealed that pig farmers' knowledge indices were affected by two explanatory variables: Their experience in dealing with previous livestock infectious diseases (Sig. = 0.000) and the distance from the interviewee's farm to the nearest pig farm (Sig. = 0.027) (Table 04).

Surprisingly, the negative coefficient of *Livestock disease experience* indicates a decreasing probability of a farmer being able to attain a higher knowledge index if he/she had previously coped with PRRS, FMD, or other livestock infectious illnesses. This finding differs from other studies concluding the opposite, that is to say that past experience positively affects farmers' understanding of the disease (Tiongco *et al.*, 2012). Additionally, the likelihood of attaining a higher knowledge index decreases the further away a household's pig farm is located from other farms. During the survey, it was discovered that swine farmers in Dong Nai rely on their knowledge gained through production experience and do not plan ahead of time for unexpected challenges. Moreover, interviewed farmers were only able to identify ASF clinical symptoms based on their experience dealing with ASF outbreaks in 2019.

Farmers' Attitudes toward African Swine Fever

When asked to indicate their anxiety level during local (hamlet-level) ASF outbreaks, 83.5% of surveyed households chose the highest level (Figure 04), indicating that, overall, farmers were very concerned over the course of ASF outbreaks.

In general, farmers' attitudes toward ASF significantly varied among the studied districts. Whilst 164 farmers distributed among the districts of Thong Nhat, Trang Bom, and Cam My indicated that they were highly vigilant regarding the disease, answers from most of the surveyed farmers in Vinh Cuu suggest that they were unheeding of the risks from ASF, even during the course of outbreaks in their area. An explanation for the latter attitude could be that the swine production scale was not significant enough to warrant increased vigilance from the farmers.

Table 04: Factors influencing surveyed farmers' knowledge of ASF, 2019.

Variables	Coefficient	Std. Error	Exp(B)
Livestock disease experience	***-0.661	0.188	0.517
Gender	-0.160	0.176	0.852
Pig farming experience	0.016	0.013	1.016
Educational level	-0.037	0.030	0.964
Number of pig farmers	0.037	0.098	1.038
Distance to the nearest farm	**-0.210	0.095	0.810
Total farm area	0.930	1.431	2.535
Pig herd size	0.001	0.000	1.001
Pig farming income	0.122	0.163	1.129
Model fit summary			
-2 Log Likelihood (Intercept only)		737.749	
-2 Log Likelihood		709.209	
Likelihood ratio chi-squared		28.54	
Degrees of freedom		9	
P-value		0.01	

*Note: ***, **, *Level of significance at 1, 5, and 10% respectively.*

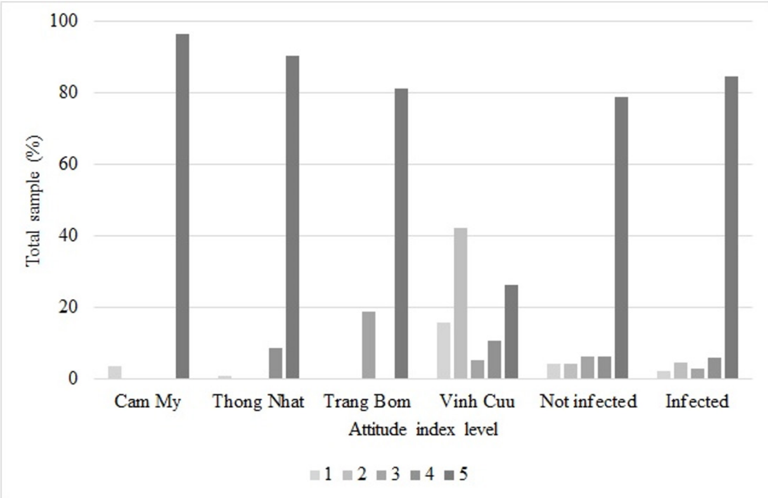

Figure 04: **Vietnam, Dong Nai province, selected districts, distribution of surveyed farmers' attitude indices toward ASF, 2019**

Furthermore, pig farmers' attitudes towards ASF were also generally reflective of their level of interest to learn more about the disease. A total of 88 surveyed farms chose the highest level on a 5-point scale to express their level of interest to learn more on ASF. Discernibly, farmers would like to have better access to information regarding ASF outbreak prevention and control measures, including being made aware of announcements and receiving regular updates on new outbreaks. To some extent, such demands indicate that farmers are for the most part self-aware that their own level of understanding of ASF is insufficient and are willing to learn more about the disease.

In the second ordered probit model, the knowledge index was used as an explanatory variable to determine its influence on the attitude index (Table 05).

Table 05: Factors influencing surveyed farmers' attitude toward ASF, 2019

Variable	Coefficient	Std. Error	Sig.
Knowledge index	***0.249	0.0652	0.000
Livestock disease experience	-0.004	0.3522	0.991
Gender	-0.066	0.2774	0.812
Pig farming experience	0.012	0.0204	0.542
Educational level	-0.015	0.0515	0.773
Number of pig farmers	0.334	0.2463	0.175
Distance to the nearest farm	0.211	0.2641	0.424
Total farm area	6.388	74.786	0.393
Pig herd size	0.000	0.0007	0.970
Pig farming income	*0.815	0.4725	0.084
Model fit summary			
-2 Log Likelihood (Intercept only)		239.687	
-2 Log Likelihood		190.7	
Likelihood ratio chi-squared		48.987	
Degrees of freedom		10	
P-value		0.000	

*Note: ***, **, *: Level of significance at 1%, 5%, and 10% respectively.*

It is estimated that for every unit increase of the knowledge index, there is a predicted increase of 1.283 in the log odds of having a higher attitude index. Also, there is an increased probability of having a higher attitude index if the household generates more income from pig farming than other economic activities. Pig production is the sole income source of around 70% of all surveyed households. Considering the fact that the ASF mortality rate for domestic swine ranges between 90 and 100% (Beltran-Alcrudo *et al.*, 2017), the more income farmers make from their pig production, the more financial losses they risk (Nguyen-Thi *et al.*, 2021). Accordingly, such households appear to be more cautious than others with regards to ASF outbreaks.

Farmers' Practices toward African Swine Fever

Most of the ASF biosecurity measures preselected as answers in the survey were implemented by at least 50% of all surveyed households in Dong Nai province (Figure 05). The most widely utilized measure was farm disinfection (84% adoption rate). Additionally, over 70% of surveyed households restricted visitors from the premises of their farm and increased the resistance of all pigs through the use of various supplements to boost their immune systems. However, only 39 farmers (20%) invited local veterinarians for a biosecurity verification of their farm to help them identify potential biosecurity risks and/or curtail the spread of ASF. Many interviewees believe that there is no cure or treatment for ASF, and therefore no use in inviting veterinarians to their farms.

In addition to the ASF biosecurity measures preselected as answers in the survey, some farmers reported burning the *Gleditsia australis* fruit as an alternative method to prevent ASF. This type of fruit, known in Vietnamese as *quả bồ kết*, has traditionally been used by livestock farmers in southern Vietnam as an herbal medicine that can help prevent respiratory depression; the fruit contains various flavonoids, such as saponaretin, which has antiviral properties (Duong, 1993).

On average, surveyed households applied eight different biosecurity measures to protect their herd from ASF (Table 06).

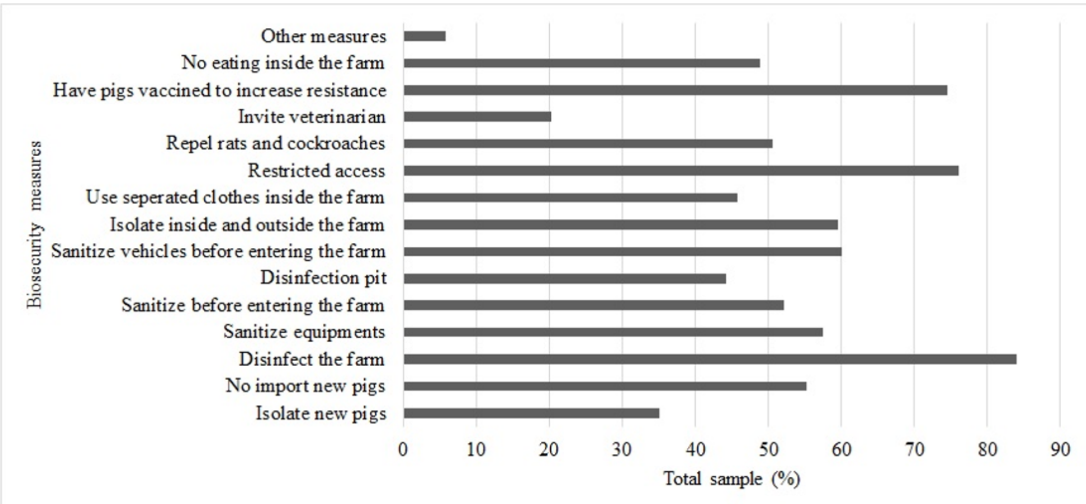

Figure 05: Vietnam, Dong Nai province, selected districts, biosecurity measures implemented by pig farmers, 2019

Table 06: Vietnam, Dong Nai province, selected districts, biosecurity measures for ASF implemented by surveyed households, 2019.

	District				Pig farms	
	Cam My	Thong Nhat	Trang Bom	Vinh Cuu	ASF infected	Not infected
Mean	10_a	9_a	6_b	3_c	9_a	8_a
Maximum	13_a	14_a	14_b	4_c	14_a	14_a
Minimum	5_a	2_a	1_b	2_c	1_a	1_a
S.D	2_a	3_a	5_b	0_c	4_a	4_a

Note: Values in the same row and sub-table not sharing the same subscript are significantly different at p< .05 in the two-sided test of equality for column means.

Households that reported pigs with ASF infections used on average 8 measures, while households with no infected pigs applied on average 9 measures. Among the studied districts, Cam My was the district where farmers implemented the most biosecurity measures, which coincidentally may explain its ASF infection rate, the lowest among the four districts. The district where farmers applied the fewest biosecurity measures was Vinh Cuu; on average, each household only implemented 3 measures, with the maximum value of this district being only 4. Results from Vinh Cuu may also reflect the negative correlation between the production scale and the disease prevention behavior of swine farmers. Also, when asked about the difficulties faced when implementing ASF preventative measures, the issues most mentioned by farmers in all surveyed districts were 1) an insufficient understanding of the disease itself (45.2%) and 2) a lack of knowledge on pig care in general (33.0%), and finally 3) the high costs of pig raising and breeding (30.8%). Another barrier to the adoption of ASF biosecurity strategies is the financial cost for farmers to adhere to proposed prevention and control measures: 33% of surveyed farmers stated that ASF prevention costs were far too high for their financial capacity. During the 2019 wave of outbreaks, farmers had to constantly pay for antiseptics, disinfection, medicine, and supplements, which drastically increased production costs. The cost of biosecurity measures was also found to influence the motivation of livestock farmers in Japan (Makita *et al.*, 2020) and in Uganda (Ouma *et al.*, 2018). Moreover, Mason-D'Croz *et al.* (2020) reported that ASF had the double-effect of reducing both household income and the average per capita calorie count of people in China.

Finally, the factors influencing the probability of farmers implementing biosecurity measures pertaining to ASF were estimated (Table 07).

Results from the panel-data probit model revealed that the probability was positively associated with 1) the knowledge index, 2) the attitude index, 3) previous experience with livestock infectious diseases, 4) the distance to the nearest pig farm, 5) the total farm area, and 6) the herd size. The estimation confirmed the initial assumption that a farmer's level of knowledge and attitude toward ASF would significantly influence their decision to adopt or not proposed biosecurity measures: As the knowledge index increases by one unit, the likelihood of a farmer adopting a biosecurity measure increases from 1.52 to 3.4. In the sample, the number of implemented measures changed significantly according to knowledge scores (these differences are statistically significant at 1%). Farmers with knowledge indices of 3 or 4 only applied 2 to 4 measures, while those with knowledge indices of 5 or higher implemented considerably more measures. People who had the highest knowledge index implemented ten or more practices.

Table 07: Factors influencing the probability of households implementing biosecurity measures for ASF, 2019

Variables	B	Std. Error	Exp(B)
Knowledge index	***1.270	0.1809	3.560
Attitude index	***1.064	0.1827	2.898
Livestock disease experience	**0.240	0.0946	1.271
Gender	0.052	0.095	1.054
Pig farming experience	-0.007	0.0057	0.993
Educational level	-0.001	0.0177	0.999
Number of pig farmers	0.034	0.0393	1.034
Distance to the nearest farm	**-0.132	0.0514	0.876
Total farm area	*-1.453	0.764	0.234
Pig herd size	*0	0.0002	1
Pig farming income	0.036	0.0652	1.036
-2 Log Likelihood (Intercept only)		239.687	
-2 Log Likelihood		190.7	
Likelihood ratio chi-squared		48.987	
Degrees of freedom		10	
P-value		0.000	

*Note: ***, **, *Level of significance at 1, 5, and 10% respectively.*

Similarly, a higher attitude index was found to increase the probability of a farmer implementing biosecurity measures. This is consistent with findings from Manabe *et al.* (2012), who determined that the level of concern prior to infectious disease outbreaks had significant impacts on peoples' behaviors, namely influencing people to be more proactive with regards to adopting protective measures. Knowledge and attitude were also enhanced biosecurity practices of pig farms in Japan (Makita *et al.*, 2020). In contrast, a case study of KAP toward ASF in Uganda indicated that poverty negatively influenced the behaviour of actors in the value chain as they purchased and sold infected live pigs, corpses, and pork (Chenais *et al.*, 2017).

This study found that surveyed farmers who felt little to no concern toward local ASF outbreaks implemented fewer than five ASF control measures, while farmers who expressed greater levels of concern were found to have higher knowledge indices and more applied practices (these differences are statistically significant at 1%). Farmer knowledge, cooperation, compliance with regulation, as well as habits were previously mentioned as contribution to the rapid spread of ASF in Vietnam (Woonwong *et al.*, 2020).

Study findings also show a positive correlation between previous experience with livestock diseases and the probability of implementing biosecurity measures. Farmers that previously had to deal with FMD, PRRS, or other infectious swine diseases tend to have 1.27 times higher odds of adopting ASF biosecurity measures.

Among the statistically significant variables, the distance to the nearest farm and the farm's total area displayed negative influences on the dependent variable; the probability of a farmer adopting ASF control practices decreases as the surveyed farm is located further away from other pig farms or has a larger total area. The negative coefficient with the distance to the nearest farm may occur since isolated farms might have fewer chances of contact with sources of infection, thus making farmers feel that there is less of a need for adopting biosecurity measures. A similar correlation was noted in a study on the KAP of Kenyan livestock producers (Tiongco *et al.*, 2012). Here, the negative effect between farm area and biosecurity adoption probability could be attributed to the costs of implementing such practices. Larger farms require more expenditures for disinfection, sanitation, and various supplements, a fact that makes farmers more selective when choosing which ASF biosecurity measures to adopt.

Finally, it was found that the herd size of farmers in Dong Nai province was another significant variable, though its impact was trivial since the odds ratio was 1. This issue can arise since the unit of measurement for the herd size was each individual pig, which is quite small compared to the size of a meaningful probability change. Therefore, when the farm's herd increases or decreases by one individual pig, there will be no remarkable change in the adoption probability.

CONCLUSION

The introduction of ASF in Vietnam in 2019 has had devastating impacts on the country's swine population and the livelihoods of smallholder swine farmers, despite efforts to prevent and control the disease's spread. Given how little is known on the drivers of outbreaks, especially the underlying factors explaining the low levels of biosecurity on smallholder farms in Vietnam, this paper assessed through survey work and regression modelling the KAP of smallholder swine farmers toward ASF in Dong Nai province. Key findings from this study indicate that that the level of understanding of ASF can significantly influence swine farmers' attitudes toward the disease. It is also concluded that pig farmers' knowledge and attitudes toward ASF are crucial factors that can influence their decision on whether to adopt or not proposed biosecurity measures.

Based on this study's findings, and in line with those of other studies on farmers' KAP towards ASF in different parts of the world, this paper suggests that policy and decision makers strongly consider improving the effectiveness of educational campaigns for ASF prevention and control.

There also needs more consideration of the socioeconomic conditions of swine farmers in order for appropriate livestock biosecurity measures to be adopted. One way forward would be more increased focus on capacity building, a growing trend in Southeast Asia (Luskin *et al.*, 2021; Aiyar and Pingali, 2020). Rising production costs are significant financial hurdles for smallholder swine farmers, and therefore more financial support is one key way of helping overcome the financial challenges restricting some farmers' capacity to adopt and implement ASF biosecurity measures (Ngu Ngwa *et al.*, 2020).

The demand for financial support and compensation is not only applicable in Vietnam but also for countries across Africa and Asia where large outbreak occurred because farmers sold sick pigs to slaugherhouses and markets as they did not receive compensation (Dixon *et al.*, 2020; Blome *et al.*, 2020). Moreover, the exposure to pork trade can also pose threats to endemic asian pigs (Luskin *et al.*, 2021).

This paper contributes to the growing body of literature on ASF by addressing calls to better understand how KAP frameworks can be used in different geographical contexts to identify underlying factors behind infectious disease transmission.

Due to time and resource constraints caused by COVID-19 disruptions, this study faced several limitations. For one, no analyses were done on ASF prevention and control activities of other agents of the pig production chain, such as private enterprises, traders, middlemen, and slaughterhouses. Second, the effectiveness of ASF biosecurity measures implemented by farmers was not assessed. Third, it is unknown how many asymptomatic pigs died of ASF on the farms of surveyed households. Finally, it was not possible to further investigate claims made by two surveyed farmers and three key informants that there were reportedly some farmers in Dong Nai province during the wave of ASF outbreaks in 2019 who (illegally) sold (at below market price) infected pigs to local middlemen. These claims point to a growing trend of illegal pig and pork exports to China, as well as to a surge in imports from Thailand and Cambodia to compensate domestic shortages of pork products caused by ASF-related pig losses (Lien, 2021). This type of practice has been documented in other nations, especially in the developing world (Gulenkin *et al.*, 2011). Such reports in Vietnam therefore warrant further investigation given how the illegal trading of pigs and pork products is known to be a potential transmission route for ASF both into and out of the country.

Conflicts Of Interest

The authors have declared that they have no conflict of interest that is relevant to the content of this study.

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