EVALUATING LOSSES ASSOCIATED WITH AFRICAN SWINE FEVER IN THE PEOPLE'S REPUBLIC OF CHINA AND NEIGHBORING COUNTRIES

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ASIAN DEVELOPMENT BANK

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ACKNOWLEDGMENTS

ABBREVIATIONS

ADB	Asian Development Bank
ASF	African swine fever
FAO	Food and Agriculture Organization of the United Nations
FAOSTAT	Food and Agriculture Organization Corporate Statistical Database
FMD	foot-and-mouth disease
GHG	greenhouse gas
GMS	Greater Mekong Subregion
Lao PDR	Lao People's Democratic Republic
PRC	People's Republic of China
OIE	*Office International des Epizooties* (World Organisation for Animal Health)
SPS	sanitary and phytosanitary standards
TAD	transboundary animal disease
USDA	United States Department of Agriculture
WHO	World Health Organization

ABSTRACT

The introduction and spread of African swine fever (ASF) in the People's Republic of China (PRC) and through many areas in Southeast Asia underscores the importance of animal diseases in economics and trade in the region. The PRC raises approximately 50% of the world's pigs; an industry worth over $128 billion. The industry is an essential component of the national economy and source of livelihood and food security for much of the population. Current estimates indicate that at least 25% and perhaps as much as 55% of the PRC's national herd has been lost to the disease and culling since it was first reported. Its impacts on livelihoods and food security in neighboring countries are equally disastrous.

To assist policymakers in assessing the scale of the impact, this paper employed a deterministic analysis and approach to estimating the direct costs of the disease. The results indicate direct costs of ASF on the PRC and neighboring countries of $55 billion–$130 billion. Of this, $28 billion–$46 billion were attributed to initial losses to disease and culling, $4 billion–$7 billion to the cost of replacement breeding animals, and $23 billion–$77 billion in revenue forgone. However, if the disease was successfully contained in Liaoning Province, initial losses would have been $3.6 billion–$5.2 billion. The burden of the disease is falling disproportionately on smallholders—for whom pig raising is often a critical livelihood mechanism and safety net—in absolute terms and on a per pig basis, thereby threatening increases in poverty, vulnerability, and food insecurity. Exacerbating this, the supply side shock is driving up pork, other food, and general prices for consumers. The effects of the disease on human health security, trade, the climate, climate change resilience, and local environments are also substantial.

The ASF epidemic highlights the massive economic and human costs associated with it and the potential costs of other animal disease outbreaks in the future. There is an urgent need for regional investment in animal health system infrastructure, capacity building, and policy to reduce the likelihood and costs of current and future animal diseases and zoonoses. Further research is needed to better inform national and regional decision making, and direct investments in animal and zoonotic disease prevention, monitoring, and control.

I. INTRODUCTION

1.   The economic burden of animal diseases is recognized to be substantial. Disease characteristics, the susceptibility of animal populations and environmental factors determine rates of infection, mortality, and impacts on productivity in animals and may directly, in the case of zoonoses,[1] affect human health (Rushton et al. 2018). Meanwhile, loss of livestock, trade, decreased market value, food insecurity, environmental impacts, and efforts to respond to animal diseases all come at considerable costs to livelihoods and both public and private sector interests (Barratt et al. 2019). Endemic and emerging transboundary animal diseases (TADs) threaten livestock producers in Asia, hampering livestock productivity, causing market disruptions, and inhibiting formal trade production animals and products. Knight-Jones and Rushton (2013) estimated the global costs of foot-and-mouth disease (FMD) alone to be $21 billion.

2.   An estimated 75% of emerging infectious diseases are zoonotic and some 61% of human pathogens are zoonoses (Jones et al. 2008 and World Health Organization [WHO] 2006), leading to high costs in healthcare, lost labor, lost tourism, and reduced export market access. The World Bank (2017) estimated that East Asia and the Pacific have the highest vulnerability to economic losses from pandemics, estimating annual losses of $200 billion, which equates to 0.9% of the region's gross domestic product. The global direct costs of zoonotic diseases, specifically, has been estimated at more than $20 billion and indirect losses at over $200 billion to affected economies (Barratt et al. 2019 and World Bank 2010). In addition, foodborne pathogens and rising antimicrobial resistance (AMR) threaten human health and are often integrally linked to animal production and products. Worldwide, more than 600 million cases of foodborne illness are estimated to occur each year, costing human health over 5.5 million disability-adjusted life years and causing over 400,000 deaths (Havelaar et al. 2015). Resistant pathogens currently cause an estimated 700,000 deaths per year globally, which, if left unchecked, is expected to reach 10 million deaths and a global cost $100 trillion by 2050 (O'Neill 2014). Overuse and inappropriate use of antimicrobials in animal production is a key driver of AMR. The current high use of antimicrobials in animal production in Asia is expected to grow dramatically in the coming years with further intensification of livestock industries (Van Boeckel et al. 2015). Control of TADs is essential to reduce current and future reliance on antimicrobials, particularly in light of the likely heightened risk of disease emergence and spread due to the effects of climate change.

3.   The introduction and spread of African swine fever (ASF) in the People's Republic of China (PRC) in August 2018 and subsequent spread through much of Asia had highlighted the importance of animal diseases. The PRC alone raises approximately 50% of the world's pigs; an industry worth over $128 billion. The industry is an essential component of the national economy and a critical source of livelihood and food security for much of the population (Gale et al. 2019). Current estimates are that at least 25% and perhaps as much as 55% of the PRC national pig herd has been lost to the disease and culling since it was first reported (World Grain 2019 and Mackenzie 2019). It will take years of herd-rebuilding for the industry to fully recover and with the disease now effectively endemic, challenges will remain at least until such time as an effective vaccine becomes available (McCracken et al. 2019). Although the scale of the PRC pig production dwarfs the impacts of ASF in neighboring countries, the impacts on livelihoods and food security will be equally catastrophic. For example, in Viet Nam, which has a similarly high per

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[1]   World Health Organization (WHO) defines a zoonosis as "any disease or infection that is naturally transmissible from ver-tebrate animals to humans. Animals thus play an essential role in maintaining zoonotic infections in nature. Zoonoses may be bacterial, viral, or parasitic, or may involve unconventional agents. As well as being a public health problem, many of the major zoonotic diseases prevent the efficient production of food of animal origin and create obstacles to international trade in animal products." WHO. Health Topics. Zoonoses. http://origin.who.int/topics/zoonoses/en/.

capita pig production and pork consumption, the pig population has decreased by as much as 40% in the worst affected areas and at the time of writing, over five million pigs had been culled in response to the disease (Food and Agriculture Organization of the United Nations [FAO] 2019).

4.   The true burden of the disease is unlikely to ever be fully accounted for. The paucity of accurate production data, likelihood of misdiagnosis and underreporting, political incentives, complexity of assessing indirect costs and the difficulties of accounting for impacts on human health and nutrition, loss of livelihoods, and less tangible impacts such as effects on social capital, make accurate assessment problematic. However, it is critical to policymaking and the provision of resources to mitigate risk and control diseases that attempts are made to assess the scale of the impact. Initial estimates are presented here based on the use of simple deterministic methods in a number of scenarios. This paper reports on preliminary analysis of the potential economic burden of direct costs of ASF on the PRC and neighboring countries of the Greater Mekong Subregion[2] (GMS) which had, at the time of writing, confirmed the presence of the disease. The results are discussed in relation to the more complex indirect impacts of the disease. This paper also touches upon other important endemic and emerging diseases that affect, or could affect, animal production, trade, economic development, and human health in the region. Investments necessary to reduce the burden of future disease outbreaks in animal production are identified in this paper and an urgent call for further research in this area is issued.

II.   BACKGROUND

5.   ASF is caused by the ASF virus, a highly resilient DNA virus with no effective vaccine at present (Gallardo et al., 2009 and Halasa et al. 2018). The highly virulent strain of Genotype II currently circulating in Asia has an estimated case fatality rate of 90%–95% in pigs (Gallardo et al. 2017 and Chenais et al. 2019). ASF typically presents with sudden death or, with less virulent strains, a high fever, generalized reddening of the skin, listlessness, congestion, and generalized hemorrhage of the lymph nodes and internal organs (Zhou et al. 2018 and World Organisation for Animal Health [OIE] 2019a). The virus may be transmitted via direct animal contact, through feeding of contaminated meat or products, and via vectors[3] (*Ornithodoros* soft ticks) or fomites.[4] Efforts to control this devastating disease are severely hampered by the lack of an effective vaccine and subsequently rely on disease reporting, culling, biosecurity, market closures, and movement bans and surveillance efforts to limit transmission, which, of course, come at considerable cost.

6.   The first confirmed outbreak of ASF in Asia was reported in a farm in Shenyang City, Liaoning Province in August 2018 (Ge et al. 2018, Zhou et al. 2018, and Li and Tian 2018). All 400 pigs at the farm died within 1 month of the first clinical signs, and the farm, like many others subsequently, was abandoned (Zhou et al. 2018). The virus was introduced to the PRC from eastern Europe seemingly

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[2]   GMS countries include Cambodia, Lao People's Democratic Republic (Lao PDR), Myanmar, the PRC, Thailand, and Viet Nam. This study does not include Thailand, however for the purposes of brevity, this paper will refer to the countries as GMS.

[3]   WHO define vectors as: "living organisms that can transmit infectious diseases between humans or from animals to humans. Many of these vectors are bloodsucking insects, which ingest disease-producing microorganisms during a blood meal from an infected host (human or animal) and later inject it into a new host during their subsequent blood meal. Mosquitoes are the best-known disease vector. Others include ticks, flies, sandflies, fleas, triatomine bugs and some freshwater aquatic snails." WHO. TDR. Diseases and Topics. Vectors. https://www.who.int/tdr/diseases-topics/vectors/en/.

[4]   A fomite is an inanimate object or substance that may be contaminated with infectious organisms and serve in their transmission between individual hosts.

through anthropogenic factors, in all likelihood via contaminated meat or pork products incorporated into swill feed. Since the first outbreak, over 160 ASF outbreaks have been confirmed in 32 provinces, autonomous regions, municipalities, and Special Administrative Regions in the PRC (Food and Agriculture Organization of the United Nations [FAO] 2019). The disease has subsequently spread to Viet Nam, Cambodia, the Democratic People's Republic of Korea, the Lao PDR, Myanmar, the Philippines, the Republic of Korea, and, most recently, Timor-Leste. It is likely that it will spread further in Southeast Asia, to Micronesia and Polynesia, and beyond.

7.   The responses to ASF had been severe by necessity. Widespread culling had been implemented in all affected countries; generally culling of all animals on farms with confirmed cases, testing of neighboring farms and farms with a direct connection to infected herds. Movement bans and market closures had been enacted. Heightened monitoring had been implemented to the degree feasible. Compensation systems had been established to varying degrees. Extensive awareness raising campaigns had been developed, encouraging reporting of any suspicious disease and improved biosecurity measures.

III.   METHODOLOGY

8.   This analysis sought to assess the scale of direct production costs associated with the ASF epidemic on the PRC and neighboring GMS countries in which the disease had been confirmed by October 2019. The direct costs were assessed in terms of initial stock losses due to the disease and culling and loss of value due to morbidity, the costs of replacing lost breeding animals to return supply to levels prior to the outbreak, and the revenue forgone during the period of herd rebuilding. Although this is not an exhaustive assessment of direct costs, it does constitute the major direct costs in the case of ASF, with the exception of the impact of the feed industry. This analysis does not attempt to quantify the indirect costs of the disease—such as the costs of control efforts, economic loss incurred in other affected commodity markets, loss of livelihoods, reduced household spending—though the potential impacts are considered in the discussion section (Barratt et al. 2019). Further research is undoubtedly needed.

9.   A deterministic approach was used to assess the direct costs of the ASF epidemic. The analyses were carried out in the statistical software R and using the FAO Livestock Development Planning System, version 2 herd dynamic model run in Excel (Lalonde and Sukigara 1997, R Core Team 2019). Pig population data was sourced from the Food and Agriculture Organization Corporate Statistical Database (FAOSTAT) and figures from 2017, prior to the ASF outbreak, or the most recent available prior to that year were used. Herd demographics (Figure 1) were estimated on the basis of the literature and expert consultation (Smith et al. 2019 and Deka et al. 2014). Disease and production parameters were derived from literature review and discussion with experts in the field and corroborated through media reports. Sensitivity analyses were conducted using minimum and maximum values for disease characteristics and reported and/or estimated production figures. Total direct losses were calculated for 30% and 50% infection rates, as had been reported for the PRC (World Grain 2019 and Mackenzie 2019). A conservative mortality rate of 90% was used, which had been reported for the strain (II) currently circulating in the region by Chenais et al. (2019), although up to 95% case fatality had been reported for this strain elsewhere (Gallardo et al. 2017). National pork demand and consumption figures were obtained from various sources including the United States Department of Agriculture (USDA) and online reports. Hog price data used were average reported prices for pigs per kilogram liveweight (prices for prewean piglets, weaner-grower-finishers, and sows) using figures from as close to the time of the outbreak as possible (USDA 2016, USDA 2019, FAOSTAT 2019, Zhang 2019, and Nga et al. 2015). The methods used are further detailed in Appendix 1 and the parameters used are detailed in Appendixes 2 and 3.

Figure 1: Herd Numbers and Approximate Demographics Prior to the African Swine Fever Epidemic by Production System and Production Stage
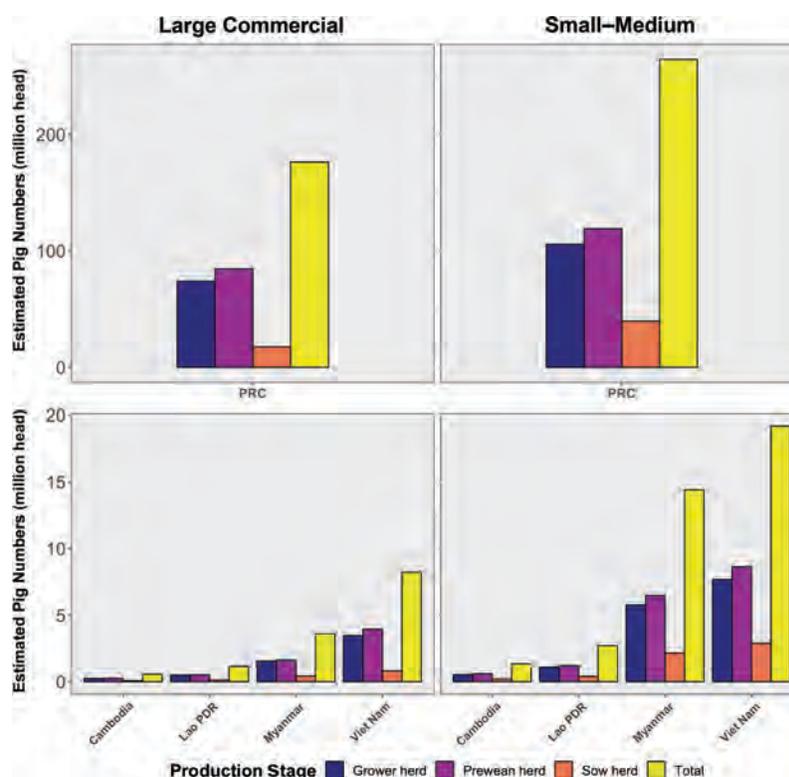
Lao PDR = Lao People's Democratic Republic, PRC = People's Republic of China.

Note: production system = large intensive commercial vs small–medium scale; production stages = sows, prewean, weaner-grower-finisher accessed 29 October 2019.

Source: Asian Development Bank; Food and Agriculture Organization Corporate Statistical Database. 2019. ASF Situation in Asia Update. http://www.fao.org/ag/againfo/programmes/en/empres/ASF/Situation_update.html (accessed 29 October 2019); National Bureau of Statistics of China. 2018. National Data. http://data.stats.gov.cn/english/easyquery.htm?cn=E0103&f=912 (accessed 7 November 2019).

A.   Caveats and Assumptions

10.   As indicated, this paper presents a preliminary analysis and there are a number of important caveats and assumptions to consider. FAO (2016) highlights the paucity of production and price data as a major challenge in assessing the impacts of animal diseases, this is certainly the case in this instance (Phipps 2019). The figures used are the most recent available from national census data (obtained from FAOSTAT) and validated with reference to other studies, but their accuracy is uncertain given the nature of pig farming in the region and high numbers of frequently unregistered smallholders and estimates of pig inventories and losses in the PRC vary widely. Other factors beyond ASF had affected pig production, such as the new environmental protection law, which had led to the closure of many small pig breeding farms and forced many large-scale farms to relocate to the northwest (Zhang 2019).

11.   The costs to the feed industry were not assessed, which will be substantial. This analysis does not attempt to quantify indirect costs of ASF, which are undoubtedly extremely high but are very challenging to estimate given the high complexity and data-related issues. This was deemed beyond the scope of this preliminary analysis but certainly warrants further investigation.

12.   In terms of disease characteristics, a simple deterministic approach was adopted. Key parameters were obtained from literature and through expert consultation. Sensitivity analysis was conducted and "lower" and "higher" estimates provided based on two scenarios. This deterministic approach radically simplifies the epidemiological characteristics of the disease's progression for the purposes of assessing short-term direct costs on production. We assume farms have an equal chance of being infected, i.e., there are no clustering effects. This was considered a reasonable assumption at the beginning of the outbreak due to the prevalence of swill feeding among the (formerly) ubiquitous smallholder subsector. However, now that large commercial suppliers, in particular, have strengthened biosecurity measures considerably, this is likely no longer valid. No attempt was made to account for intraherd transmission rates, or to use more complex transition models of disease spread or of different modes of transmission, such as considering potential effects of farm input supply, product and/or live animal and/or vector and/or fomite transmission pathways, to the role of wild pigs, etc., in clustering. Due to the issues with data and wide-ranging assumptions, this study did not account for uncertainty in the analyses since this would potentially be misleading by portraying the results as more robust than they in fact are; given the stakes at hand, transparency of methods is paramount. Further epidemiological, economic, and sociological research in this area is crucial and necessary.

13.   Pig prices used in this study were national averages for the PRC for 2017, the year prior to the ASF outbreak. The PRC pig prices were used because regional pig prices have been highly volatile relative to other meat and animal prices in recent years and reliable price data was difficult to obtain for all of the study countries. However, local prices within the PRC and the region undoubtedly vary considerably and there are certainly seasonal price trends. It was also assumed that pig prices would remain stable during and in the aftermath of the epidemic, therefore, this analysis underestimates the costs of replacement of breeding stock and revenue forgone. Demand for replacement stock is likely to be heightened although there are less farms, while supply has been dramatically reduced. This is easily observed in the PRC and global pig and pork prices.

14.   Finally, the value of pigs that succumbed to ASF or were culled was assumed to be zero. However, it is likely that pork from some of these pigs had been consumed or sold. Given that there was no way to reliably estimate the volume or value of this, it was not included in the analysis.

IV.   RESULTS

15.   Costs of direct losses in the PRC and neighboring GMS countries in which ASF had been confirmed were estimated to be between $55 billion–$130 billion (Table 1 and Figure 2). To provide an idea of the scale of these losses, the United States pork industry is estimated to contribute approximately $40 billion to the country's gross domestic product (National Pork Producers Council no date). Of these costs, $28 billion–$46 billion were attributed to initial losses to disease and culling. Assuming losses of 30%–50% of the national breeder herd, to restore the breeder herd to the levels necessary to meet the estimated demand pre-ASF of 55 million tons of pork per year requires some 11 million–12 million heads to be diverted from the market into the breeding herd (approximately 10.5–22.0 million gilts and 0.4 million–0.8 million boars) (Patton and Gu 2019 and USDA 2019). At an average price of approximately $175 per head for finished hogs (average 70 kilograms [kg] finished weight for smallholders and 90 kg for intensive producers [Appendix 1]) diverted to replacement gilts and boars, the estimated direct cost of replacements is $4 billion–$7 billion. In addition, the loss of litters over a minimum of 1 year, or approximately two farrowings, at an average 20 pigs sold per sow per year is an additional $23 billion–$77 billion in revenue forgone, calculated on the basis of approximate average profit per finished pig averaging the PRC prices before (August 2018) and 1 year after (August 2019) (Patton 2019).

Table 1: Estimated Direct Costs of African Swine Fever on Production by Country

Country	Initial Stock Losses ($ million)		Replacement Breeders ($ million)		Revenue Forgone ($ million)		Total ($ million)	
	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper
PRC	24,956	41,594	3,851	6,543	21,486	72,981	50,293	121,118
Cambodia	108	180	8	14	44	152	160	346
Lao PDR	217	361	5	8	25	86	247	455
Myanmar	981	1,636	43	73	240	815	1,264	2,524
Viet Nam	1,518	2,530	168	286	939	3,189	2,625	6,005
Total	27,780	46,301	4,075	6,924	22,734	77,223	54,589	130,448

Lao PDR = Lao People's Democratic Republic, PRC = People's Republic of China.

Source: Asian Development Bank.

Figure 2: Estimated Direct Costs to Production by Country
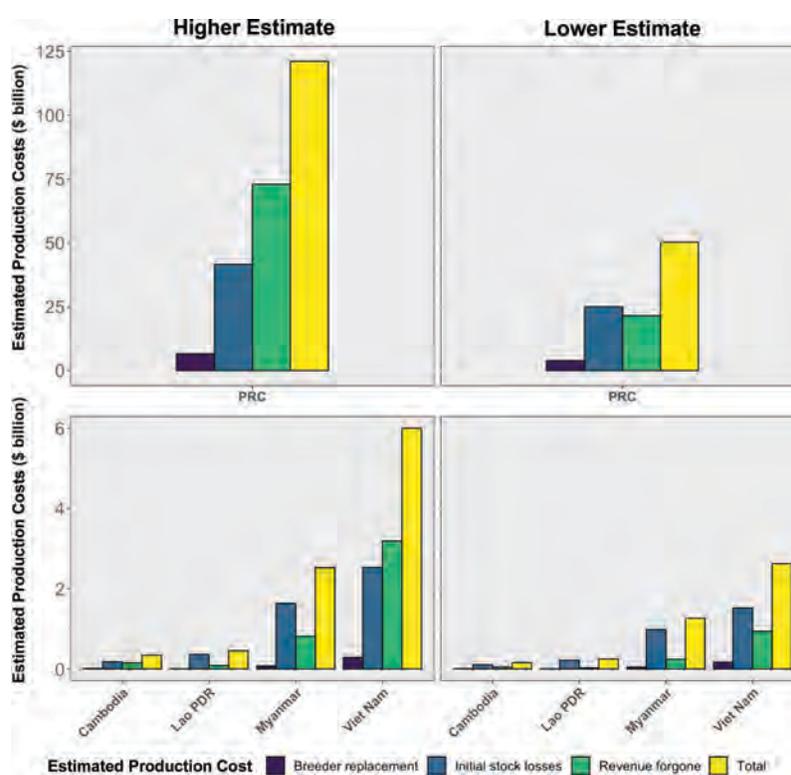
Lao PDR = Lao People's Democratic Republic, PRC = People's Republic of China.

Source: Asian Development Bank.

16.   Analysis showed that the direct costs of the disease fall more heavily on smallholders in absolute terms due to the larger number of producers and pigs and the nature of typical smallholder systems (Figure 3 and Appendix 3). Costs are higher for smallholders on a per pig basis, which is exacerbated by the higher risks and costs of preventive measures in typical smallholder systems.

Figure 3: Estimated Initial Costs of Deaths, Morbidity, and Culls of the African Swine Fever Outbreak by Production System and Country
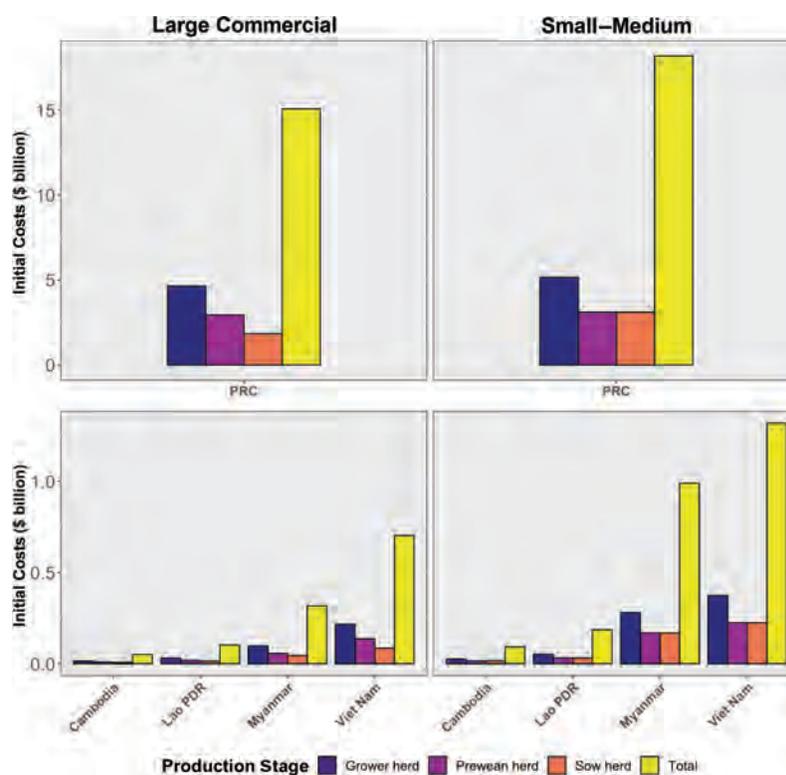
Lao PDR = Lao People's Democratic Republic, PRC = People's Republic of China.

Note: Average of the higher and lower estimates.

Source: Asian Development Bank.

17.   Disaggregating cost estimates associated with ASF within the PRC provides an indication of the pig herd structure within the PRC and likely economic impacts of the spread of the disease throughout the PRC (Figure 4). The costs are approximate to the human population of each region. The risks in less populated areas, typically with lower density of pig production, are most likely lower, and these have implications on surveillance system design, increasing the likelihood of early detection and enacting effective disease prevention and control measures.

Figure 4: Estimated Initial Costs of Deaths, Morbidity, and Culls of the African Swine Fever Outbreak in the People's Republic of China by Region and Production Stage
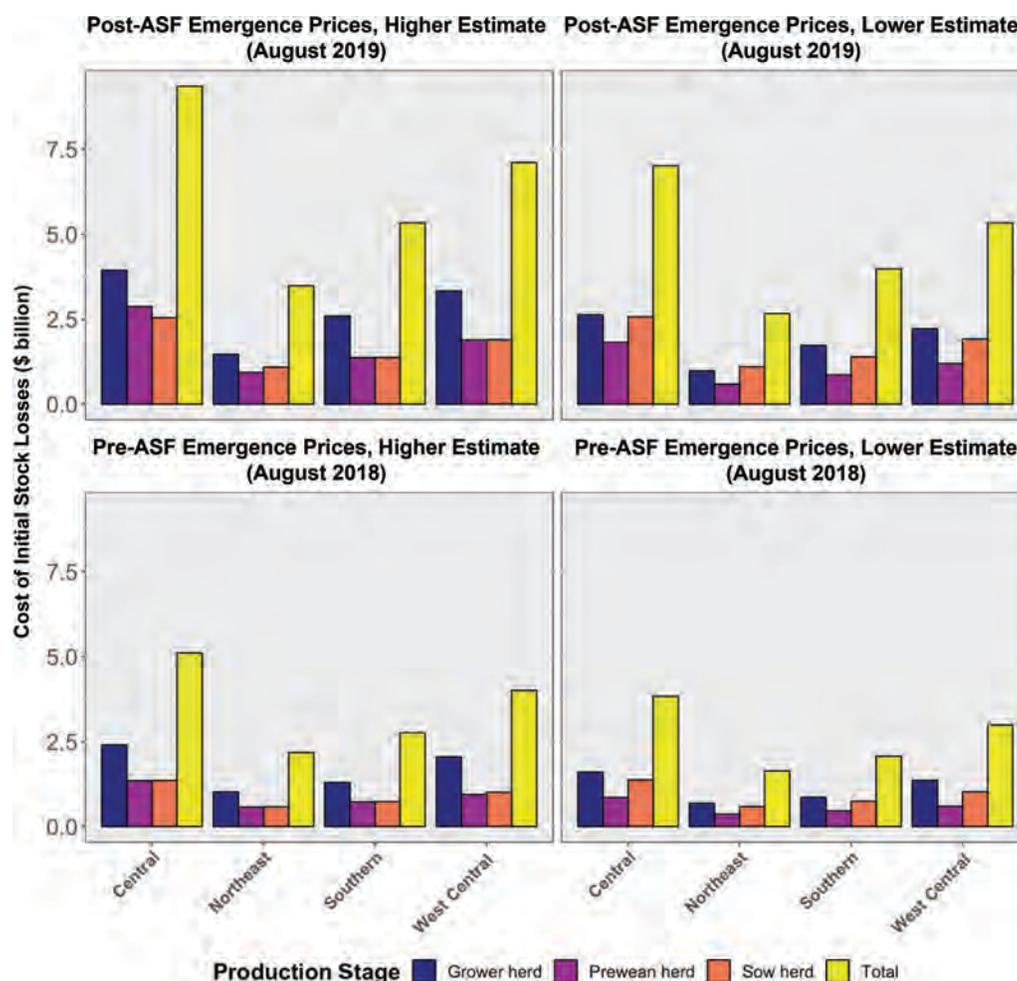
ASF = African swine fever.

Note: Higher estimates relate to an estimated infection rate of 0.5 while lower estimates are for an estimated infection rate 0. The costs are calculated on regional average prices 1 year after the initial outbreak and before the disease emerged.

Source: Asian Development Bank; National Bureau of Statistics of China. 2018. National Data. http://data.stats.gov.cn/english/easyquery.htm?cn=E0103&f=912 (accessed 7 November 2019); D. Patton and H. Gu. 2019. Swine Fever Toll in China May Be Twice as High as Reported, Industry Insiders Say. Reuters. 30 June. https://www.reuters.com/article/us-china-swinefever-production-insight/swine-fever-toll-in-china-may-be-twice-as-high-as-reported-industry-insiders-say-idUSKCN1TV017.

18.   Disaggregating the PRC pig production by province shows the disparity between provinces in terms of production volumes and the subsequent costs a disease such as ASF can have on provincial economies (Figure 5). The direct costs of stock losses and culling alone for Sichuan, the worst hit province due to its high levels of pig production and recent prevailing pig prices in the West Central region, range from $1.8 billion to $3.8 billion, unlike comparatively negligible losses in provinces like Qinghai, Ningxia Hui Autonomous Region, and Tibet Autonomous Region where pig production is limited and those producers that do operate are at lower risk due to the low pig density.

Figure 5: Estimated Initial Costs of Deaths, Morbidity and Culls of the African Swine Fever Outbreak in the People's Republic of China by Province and Production Stage
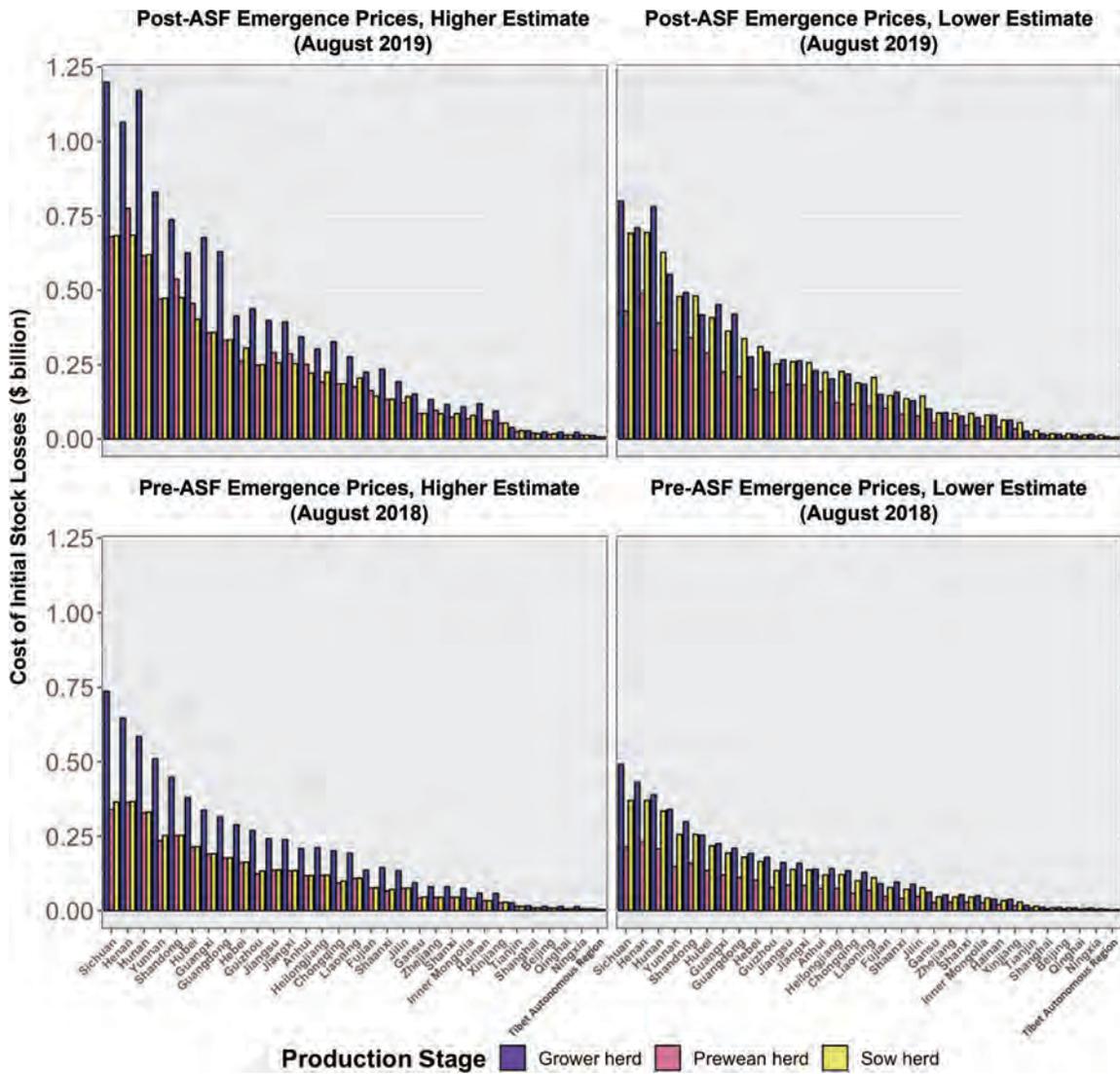
ASF = African swine fever.

Note: Higher estimates relate to an estimated infection rate of 0.5 while lower estimates are for an estimated infection rate 0.3, the costs are calculated on regional average prices 1 year after the initial outbreak and before the disease emerged.

Source: Asian Development Bank; National Bureau of Statistics of China. 2018. National Data. http://data.stats.gov.cn/english/easyquery.htm?cn=E0103&f=912 (accessed 7 November 2019); D. Patton. 2019. China Pig Farmer Profits Soar After Disease Wipes Out Third of Herd, Boosts Prices. *Reuters*. https://www.reuters.com/article/us-china-swinefever-profits-graphic-idUSKCN1VA075.

19.   The costs of an outbreak are largely dependent on the nature of the pathogen and disease and the degree to which susceptible populations are exposed. Critical to minimizing the direct and indirect costs of an outbreak is early detection and control and/or stamping out. Liaoning Province, where the first outbreak was detected, had approximately 13 million pigs at the end of 2017 according to the National Bureau of Statistics of China (NBS no date). Simplistically, were the disease to have been limited to Liaoning Province (in effect shortening the epidemics progression spatially and temporally), the production costs of the disease and culling responses—including replacement of breeders and revenue forgone—would have been about $3.6 billion–$5.2 billion (Figure 6). If the outbreak had been controlled in the Northeast region of the PRC, the costs would have been about $18 billion–$28 billion. As the outbreak had spread through the PRC and to neighboring countries, the direct costs are likely to be at least $55 billion–$130 billion, without accounting for losses in Indonesia, which had since reported the disease, the Democratic People's Republic of Korea, the Philippines, the Republic of Korea, Timor-Leste, and other countries that are currently at risk. Stamping the disease out even earlier, which is conceivable with highly sensitive surveillance systems and effective responses, would potentially reduce the total costs to the economy, livelihoods, and food security to comparatively negligible levels.

Figure 6: Estimated Direct Costs of Hypothetical African Swine Fever Control Scenarios
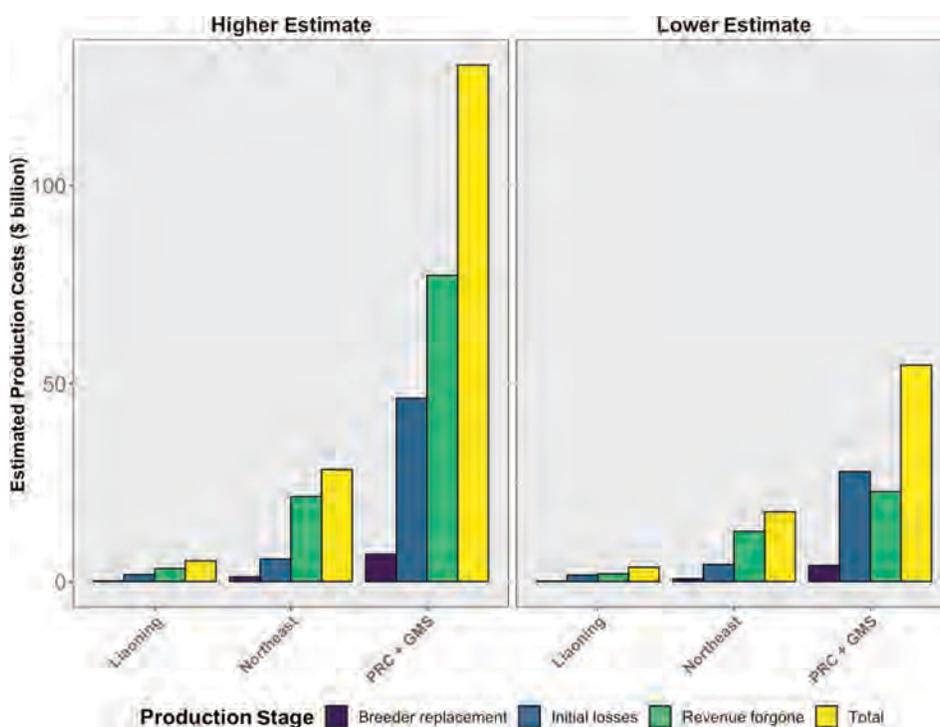
GMS = Greater Mekong Subregion, PRC = People's Republic of China.
Source: Asian Development Bank.

V. DISCUSSION

20.   Based on available data, the estimated direct production costs of ASF losses, replacement breeding stock, and revenue forgone in the PRC and neighboring countries are likely to be around $55 billion–$130 billion. This is realistic when one considers the costs estimated for other animal disease outbreaks and that approximately 50% of the world's pigs are raised in this region. As referenced previously, Knight-Jones and Rushton (2013) estimated that the production losses and vaccination costs of FMD were approximately $21 billion in the early 2010s. The FMD virus is a considerably more infectious agent but with far lower associated mortality rates and, importantly, effective vaccines and vaccination programs in place in many countries. When one considers the enormity of the PRC and broader east Asian pig industry and the scale of the outbreak, it is eminently plausible that the costs of production losses will run to between $50 billion and $120 billion for the PRC alone, and an additional $5 billion–$10 billion in the other GMS countries where outbreaks have occurred should the disease progress in a similar fashion to what occurred in the PRC.

21.   In this analysis, the costs to the animal feed industry and other allied industries—such as animal and pork traders, slaughterers, animal health workers, pharmaceutical manufacturers, distributors, and so forth—were not considered. These costs will likely rise into billions of dollars as indicated by studies of the economic impacts of other diseases (Barratt et al. 2019 and World Bank 2010). The costs of responses beyond culls were also not accounted for, which are likewise substantial when one considers the scale and organization required and the logistical challenges of communicating and working closely with the industry and communities, detecting and monitoring the disease, establishing protection and surveillance zones, establishing and enforcing movement bans and market closures, the acts of culling and disposing of carcasses themselves, and the effective decontamination of farm premises.

22.   The initial impact of losses through deaths is amplified by the costs of replacing lost animals— diverting terminal lines to breeders and/or purchasing new breeder and/or weaner stock—thereby reducing the number of pigs reaching the market and causing a lag in supply while herds rebuild. This massive supply side shock has and will continue to drive up pig prices in the PRC and pork imports among other products in the short-term, thereby driving up pig and pork prices in the global market. According to data from the Ministry of Agriculture and Rural Affairs, Beek (2019) observed that reduced pork supply led to record high prices in early August 2019, reaching a national average of CNY35.12 per kg—a 57% rise on prices in August 2018, prior to the outbreak (Ministry of Agriculture and Rural Affairs 2020). The authors note that the Ministry of Agriculture and Rural Affairs is projecting a 70% rise in the price of pork by the end of 2019, which they consider a conservative estimate.

23.   The ASF epidemic has demonstrated the enormous impact a catastrophic disease outbreak can have on supply of a critical foodstuff and prices for the products of animals that are directly affected as well as other foods and effects that ripple through other sectors. The knock-on effects on other foods, particularly the price of other meats in the PRC are already notable. Chicken, beef, and lamb prices have all risen in response to increased demand and high pork prices. High pork prices are affecting the broader consumer price index. Horton (2019) cited a Nomura International analysis that found that in May 2019, the consumer price index for the PRC rose 2.5% year-over-year, which they largely attributed to rising pork prices. The index is expected to rise by more than 3% in the coming months. This will impact food security for many, especially given the large number of smallholder households who have lost an important income stream to the disease. Rural households are often net buyers of food. The impact of ASF on livelihoods also needs to be considered in relation to consumer price effects and how they impact food security. Further research into the costs and effects of ASF on livelihoods, particularly those of the poor and vulnerable, and consumer prices and food security are needed.

24.   The rise in the PRC consumer price index is complex and likely confounded but provides an indication of some of the substantial indirect costs of ASF on the PRC economy and other countries suffering from the disease, which will inevitably have repercussions in global markets. Calculating the indirect costs is extremely complex and beyond the scope of this paper. However, for such a critical disease it is reasonable to assume that the total indirect costs of the ASF epidemic to society will be greater than its direct costs (Barratt et al. 2019 and World Bank 2010).

25.   The impacts of ASF on trade are already proving substantial. Undersupply of pork in the PRC is driving imports and pushing up international prices. The PRC is a massive importer of critical feed components such as soybeans. Diminished demand for feed components is likely to see prices in both the domestic and international market drop in the short term.

26.   Pig trade in the region has fluctuated considerably in recent years with relatively volatile pork prices affected by global and local markets and policy changes; unlike the steady flow of cattle and buffalo into the PRC and Viet Nam from South Asia and the other GMS countries through informal routes. The long land borders in the PRC and GMS region present considerable challenges for containing diseases such as ASF and as has been seen with other TADs. The porous nature of borders, currently limited agreement on formal trade between countries, and laborious and costly nature of formal routes encourages the use of informal pathways. This hampers disease monitoring and risk management strategies thereby increasing the risk of disease spread. Formalizing trade will enable more effective risk monitoring and management. However, considerable investment in improved disease risk analysis and particularly risk management systems and demonstration of equivalence according to the World Trade Organization Sanitary and Phytosanitary Agreement are needed to enable formal trade between countries in the subregion.

27.   The Asian Development Bank (ADB), among other development partners including the World Bank Group and various United Nations agencies, such as the FAO and Economic Commission for Europe, had invested substantial sums in sanitary and phytosanitary standards (SPS) capacity building and trade facilitation in the region over the past decade. In this regard, ADB initiatives have primarily targeted Cambodia, the Lao PDR, and Myanmar. The OIE, among others, through the South-East Asia and China Foot and Mouth Disease project and their work on policy, regulatory and legal frameworks in the region, have also contributed effectively to promoting alignment, benchmarking, harmonization and mutual recognition of equivalence in animal disease surveillance, preparedness, communication, and broader risk analysis within the region. The OIE also supports the operation of vaccine banks and vaccine distribution, particularly in relation to FMD, in Southeast Asia and globally. There is considerable potential to support and build on these and related initiatives in the region to develop effective, efficient, and robust animal health systems that increase the competitiveness of livestock value chains in a sustainable and inclusive manner.

28.   These results demonstrate the enormous direct economic costs of ASF but fail to account for other effects on society and particularly the vast numbers of people in the PRC and neighboring countries whose livelihoods are directly or indirectly linked to pig and pork production and value chains. This includes input suppliers, live animal traders, slaughterers, meat workers, pork traders, and retailers.

29.   In much of Asia, pig raising is a critical livelihood mechanism and form of insurance in times of need. It is notable that women are frequently heavily involved in small-scale livestock production and along local value chains. In a recent example, Smith et al. (2019) note the importance of pig raising in Timor-Leste. They describe the importance of pigs to households culturally and in terms of livelihoods and as fungible savings that may be deployed in response to economic shocks, often serving as a critical means of averting poverty in vulnerable households. In Timor-Leste, the large majority of pig raising is performed in backyard systems—the authors estimate the average herd size as under three

head—in the PRC and GMS countries average herd sizes are considerably larger but the industry is numerically dominated by small-scale household run operations. However, although vast numbers of smallholders continue to raise pigs on a small scale, backyard or subsistence-type systems are largely confined to remote areas. Small, but relatively intensive fattening units and farrow to finish operations are commonplace. Large, frequently vertically integrated producers are increasingly important in terms of pig numbers, particularly in the PRC and Thailand, increasingly in Viet Nam, and to a lesser extent in Cambodia, the Lao PDR, and Myanmar.

30.   The impact of ASF in absolute terms will be higher among smallholders due to the much larger number of farms and, at present, larger total pig numbers as shown by the estimated total initial costs of deaths and culls of the ASF outbreak (Figure 3). However, the burden of the disease is also falling disproportionately on small- and medium-scale producers on a per pig basis. Countless smaller pig raisers had been driven out of the business, removing a long-held source of income and form of savings, and threatening many with poverty or increasing their vulnerability to unexpected household expenses and other economic shocks.

31.   It has generally been smallholders, unable to implement the biosecurity measures capable of mitigating the risk of ASF for practical and financial reasons and with no other means of protecting their herds (e.g., an effective vaccine), who have suffered catastrophic losses to the disease. This is particularly the case in the latter stages of the epidemic as commercial operations have invested heavily in improved biosecurity (Quilty 2019). The limited ability of smallholders to employ adequate biosecurity measures presents increased risks to neighboring herds where spatial separation is often low and preventive measures are impossible to apply in current housing. It has been estimated that introducing the biosecurity measures needed to prevent ASF incursion into large commercial operations in the PRC costs approximately $6 per pig, while the costs for small farms may be as high as $30 per pig (Quilty 2019).

32.   Subsidies provided to commercial pig operations to temper the effects of lost production on pork supply, which is important for consumers and food security, are also likely to drive further concentration of industries (Quilty 2019). Already many small- and medium-scale farms have been put out of business and many more will inevitably follow as the disease and efforts to control the disease continue. There is already considerable evidence that this has already occurred and is continuing with many smallholders forced to seek alternative sources of income (Quilty 2019).

33.   This may drive further urbanization of populations, a long-term trend associated with a variety of societal challenges (Jayanthakumaran 2016). The effects on availability of housing, food security, and the value of wage labor could have additional negative impacts on poverty and food security. The negative impacts of forced migration and additional pressure on urban areas may be felt in terms of poorer living conditions, reduced food security, increased urban poverty and vulnerability, and increased outbreaks of infectious diseases in the human population.

34.   It is likely that the disease will remain endemic without the development of an effective vaccine; and even if a vaccine becomes available the disease will continue to circulate for some time as vaccine production and coverage ramps up. The large commercial industry are touting efforts to ensure high biosecurity standards in the wake of the initial outbreaks, reporting in a substantial decline among them while smaller operations continue to suffer (Quilty 2019).

35.   Animal diseases can increase the negative effects of animal production on climate change and contribute to local environmental degradation. Livestock contribute to a majority of the estimated 10%– 12% of global greenhouse gas (GHG) emissions directly from agriculture (Reisinger and Clark, 2018). By reducing animal productivity through losses in production, animal disease, such as ASF, can increase net GHG emissions from livestock per kilogram consumed. Poorly managed waste from animal production

and supply can also contaminate local natural resources such as waterways. However, investing in reducing the threat of disease, improving productivity, and better managing waste by using anaerobic biogas digestion, for example, in supply chains, can reduce this burden. Smallholder systems tend to have a lower environmental footprint than large intensive systems, therefore, improving smallholder competitiveness by reducing disease threats, improving productivity, and increasing market access can have environmental benefits. As this analysis has demonstrated, diseases such as ASF may further drive concentration of the industry, which may increase the environmental impacts of the animal production systems. There are also opportunities to promote adoption of greener production and transport technologies, such as renewables, that can reduce GHG emissions and increase natural resource efficiency.

36.   Climate change also threatens productivity and, while complex, will likely increase the risk of TADs through effects on animal condition, vectors, and pathogen viability outside the host thereby reducing climate resilience, particularly among smallholders. Breed selection, investment in more resilient feed crops, and raising animals in buildings that improve rearing conditions by better managing heat and allowing application of more effective biosecurity measures can increase resilience to the effects of climate change, including reducing the risk of diseases such as ASF. Targeted public investment, technology transfer, and strengthened policy environments are needed to establish and promote further investment in greener livestock production, processing, and supply while increasing the resilience and long-term sustainability of animal production systems.

37.   The ASF epidemic serves to highlight the massive economic and human costs that may be associated with widespread animal disease outbreaks. Of course, while ASF is critically important as has been shown by recent events, it is far from the only animal disease affecting livestock value chains, public health, and national economies (Appendix 4). The effects of classical swine fever, porcine reproductive and respiratory syndrome, FMD, and Newcastle disease, among many others have been highlighted elsewhere, including by FAO (2016). Admitting the difficulty in accurately assessing the impact of animal diseases in much of the world, FAO (2018) estimated the global cost burden of FMD in endemic regions to be more than $6.5 billion per year with an additional $1.5 billion per year due to outbreaks in previously FMD-free countries. Zoonotic diseases pose additional challenges and entail other direct and indirect costs such as human healthcare, lost labor, and reduced tourism and tourist spending. Examples include influenza viruses, brucellosis and foodborne pathogens such as *Salmonella* spp., pathogenic *E. coli* strains, and *Campylobacter* spp. The recent isolation of the zoonotic Rift Valley Fever virus from a patient in the PRC for the first time reveals, as Liu et al. (2017) note, the very serious threat of emerging diseases and/or the spread of diseases to regions previously free of such diseases. The ASF epidemic has served to highlight the need for further investment in disease prevention and control-related infrastructure, capacity building, and policy support, on animal production diseases but also to reduce the threats of zoonoses now and in the future.

VI.   RECOMMENDATIONS

A.   Strengthening Capacity to Prevent and Control Animal Diseases

38.   The substantial reductions in costs associated with early detection and stamping out of ASF, as with other diseases, are clear. Further investments in animal disease prevention, monitoring, risk communication, and outbreak and emergency response measures are urgently needed. The ASF epidemic has highlighted the need for regional approaches to addressing TADs and zoonoses. The

increasing integration of animal supply chains and trade in the region emphasizes the need for regional approaches. Broad stakeholder engagement is essential to support and direct future investment.

39.   Regional investment in animal health systems, production, value chains, and trade will contribute to all operational priorities[5] of the ADB Strategy 2030 by strengthening rural livelihoods and food security, reducing public health risks, reducing GHG emissions and local environmental degradation, and increasing climate change resilience and fostering regional cooperation and integration (ADB 2018). This is directly aligned with the ADB Strategy for Regional Coordination, the Operational Plan of the Thematic Group on Agriculture and Natural Resources (ADB 2016a), the Operational Plan for Regional Integration and Cooperation, 2016–2020 (ADB 2016b), and the GMS Regional Investment Framework 2030 (ADB forthcoming).

Infrastructure

40.   The quality and accessibility of animal disease risk management infrastructure varies widely in the region. Establishing quarantine facilities in line with international norms and upgrading sanitary and phytosanitary-related infrastructure and laboratory facilities and equipment is needed. This can support disease prevention, monitoring, control and/or containment and the establishment of disease control zones and/or the compartmentalization of industries, thereby better protecting domestic stakeholders and neighboring countries and increasing the ability to demonstrate system equivalence to current and potential export markets (OIE 2019b). Further investment in livestock value chain infrastructure, such as breeding facilities, fattening sites, aggregation points and live animal markets, slaughtering and processing facilities, modes of distribution, and wet markets can improve productivity, assist disease monitoring, and strengthen communication and coordination among actors. There are opportunities to attract private sector investment in much of this infrastructure through public–private partnerships or by enabling policy and regulatory environments. For example, formalizing trade can reduce risk and increase the attractiveness of investment in animal production-, health- and supply-related facilities.

Capacity Building

41.   At present, surveillance capacity varies between countries. There is an urgent need to coordinate at a regional level and to build technical, leadership and management, and operational capacity in disease detection and monitoring, transparency, and risk management. Animal health services need strengthening. Regional disease monitoring and prevention systems, outbreak simulations, clearly defined communication channels, and response mechanisms can all serve to increase the likelihood of early detection and improve the effectiveness of prevention and response strategies. Incentives for disease reporting are needed to increase the likelihood of early detection and improve the efficiency and efficacy of responses. Stronger risk communication and compensation schemes, for example, need to be in place before outbreaks occur. Emergency risk communication systems within and between countries are needed to increase the effectiveness of prevention and control measures. Investment in the design and implementation of animal identification and traceability systems is needed. Building a cadre of inspectors, improving diagnostic capabilities, and increasing sampling in production and processing and of products can all serve to increase the likelihood of early detection and reduce the threat of pathogens important to both animal and human health.

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[5]   These are: (i) addressing remaining poverty and reducing inequalities; (ii) accelerating progress in gender equality; (ii) tackling climate change, building climate and disaster resilience, and enhancing environmental sustainability; (iv) making cities more livable; (v) promoting rural development and food security; (vi) strengthening governance and institutional capacity; and (vii) fostering regional cooperation and integration.

Policy Support

42.   Regional policy support is needed to coordinate and strengthen policy, legislative, and regulatory environments to mutual benefit. Formalizing trade in live animals and animal products can improve disease surveillance but variable capacity currently inhibits recognition of equivalence. The current lack of formal pathways encourages the use of clandestine methods, which hamper monitoring and heighten the risk of disease spread among countries. Additional investment in livestock statistics and economic, epidemiological, and biological research relating to critical diseases and pathogens can provide evidence for improved policymaking. Further research on disease outbreak scenarios, critical pathogens, and disease transmission risk pathways and mechanisms and potential controls, such as vaccines, is needed.

43.   More investments in aligning national SPS measures with international standards, capacity to implement SPS measures effectively, and strengthening of border services relating to pig and pork trade can reduce the risk of future emergence and spread of animal diseases (ADB 2019). Reviewing and adjusting legal provisions to support animal disease surveillance and import risk analysis, veterinary legislative reform, and the conduct of the Performance of Veterinary Services Pathway can support countries in achieving compliance with OIE standards, reduce the risk of disease, and improve the efficacy of outbreak responses.

B.   Investment Scenarios for Interventions

Business as Usual

44.   In a business-as-usual scenario, the private sector and governments will continue to invest in veterinary services and disease monitoring. However, it is unlikely that there will be considerable changes in capacity to detect disease outbreaks early and to then launch appropriate risk management responses to control and ideally stamp out the disease quickly and at minimum cost. The emergence and spread of ASF in Asia provide a stark example of current challenges facing animal disease monitoring and control. In this case, a well-known and characterized pathogen whose epidemiology and risk factors for spread have been well-described emerged and spread rapidly through the PRC despite long-term planning, preparations, and national investment in monitoring and control measures designed to contain the disease. Diseases such as FMD provide other examples of the challenges facing animal services, industries, and governments in effectively controlling infectious animal disease outbreaks in complex systems like animal production in East and Southeast Asia. In the case of less well-known or emerging diseases, early detection and control will likely be even more challenging and the risk of rapid spread and subsequent economic losses even greater.

Strategic National and Regional Investment

45.   Strategic investment programs that support national and regional animal disease monitoring and outbreak preparedness and control can be highly effective in increasing surveillance capacity and preparedness. There are critical opportunities to support regional coordination and risk communication among governments and industries. Further investment in policy alignment and coordination can strengthen regional capabilities and encourage greater and safer trade within the region. Laboratory proficiency and test reliability remain variable within the region. A critical constraint to early detection of diseases is the low number of samples collected and processed through laboratories. Low sample throughput limits the likelihood of detecting diseases early, while also hampering laboratory technician capacity development and cost recovery. There is considerable need for greater field epidemiology capacity and inspection and monitoring of sentinel sites and supply chain bottlenecks, primarily live animal markets and slaughtering facilities. Many laboratories in the region also need further support in obtaining the international accreditations necessary to attract fees for service sample submissions. Supporting policy and regulatory changes and their enforcement that incentivize better practices and

disease reporting can improve detection and reduce the spread of disease, thereby lowering costs and reducing the risks for stakeholders. Strategic investment in regional coordinating mechanisms, surveillance system capacity building, and risk communication capacity and systems can also rapidly improve preparedness and emergency responses that would benefit all.

Comprehensive Investment

46.   Major investments in laboratories and critical value chain infrastructure may be considered. However, there has been considerable investment in animal health laboratory infrastructure and equipment in the region over the past 15–20 years, notably following the emergence of Severe Acute Respiratory Syndrome and highly pathogenic avian influenza H5N1. The main constraints to improved disease monitoring and control programs are generally capacity constraints and low sampling numbers. Variable technical proficiency reduces the likelihood of early detection and increases the risk of highly costly false positives that could severely impact industries if handled poorly. Although there is a considerable need to upgrade slaughtering and animal and product marketing facilities, the high value of industries and rapidly growing demand indicate that private investment financing can be leveraged. Inspection and monitoring capacity is a public good; it is also essential for the industry. However, private funding for monitoring and regulation is unlikely to be forthcoming and has the potential to create conflicts of interest.

VII.   CONCLUSIONS

47.   This study demonstrates the high costs associated with the devastating ASF epidemic affecting Asian pigs, smallholders, industries, governments, and consumers. The effects of the disease on the larger economy, livelihoods, food security, human health security, and the environment are substantial. There is an urgent need for regional investment in animal health systems to reduce the likelihood and costs of ASF and future animal diseases and zoonoses. This study used a simplistic approach to calculating the direct costs of ASF to present initial estimates of the direct costs of the disease to date. Further analysis employing more sophisticated epidemiological and econometric modeling is needed to better inform national and regional decision making and direct investments in animal and zoonotic disease prevention, monitoring, and control.

APPENDIX 1: Methods Employed to Estimate Direct Cost of African Swine Fever

48. To estimate the direct production costs of African swine fever (ASF) in the People's Republic of China (PRC) and the neighboring countries of the Greater Mekong Subregion (GMS), which subsequently reported the disease, the study estimated the costs of losses to the disease (mortality and morbidity) and culling, the costs of lost breeders during the projected replenishment phase due to pigs being retained (or purchased) for breeding purposes, and the revenue forgone in the form of lost marketable pigs due to the time to replace lost gilts and sows.

49. To calculate initial production costs of the disease (deaths, morbidity, and culls) the study used a simple deterministic approach. Although stochastic models were considered incorporating greater accounting for uncertainty, this risked masking deficiency in the data and the number and scope of assumptions. As the intention of this analysis was to provide a starting point for more detailed and sophisticated economic assessment, a simple deterministic approach with suitable declaration of assumptions and uncertainties is believed to provide the least risk of misrepresentation.

50. The calculations employed in determining the initial losses associated with the disease were:

$$D_{Mt} = PIM_t$$
$$D_{Mb} = PIM_b$$
$$D_c = D_{Mt}V_{Mt} + D_{Mb}V_{Mb}$$

where:

D_{Mt} = disease associated mortality (due to disease and culling)

D_{Mb} = disease associated morbidity

D_C = costs of disease

P = population at risk (naïve population therefore, with no vaccination, the national pig herd)

I = infection rate/attack rate (proportion of the pig population that becomes infected and/ or are culled during disease response efforts)

M_t = mortality rate (proportion of infected that die)

M_b = morbidity rate (proportion of infected that fall ill/show clinical signs, which reduce value, but recover)

V_{Mt} = value of loss to mortality

V_{Mb} = value of loss to morbidity

51. In conducting the calculations, data was grouped by various attributes: country; production system (intensive commercial and smallholder); and production stage (sows, preweaners or suckling pigs, and weaner-grower-finishers). The number of animals by production system (commercial or smallholder) was determined using the available literature updated following consultations with experts and to reflect recent developments to national industries in subsequent years (Deka et al. 2014). The estimated fraction of the national pig herds by production stage (sow, prewean, weaner-grower-finisher) was estimated on the basis of general estimates from smallholder and commercial systems in the region and expert consultations (Smith et al. 2019). Pigs that died were assumed to lose 100% of their value while morbidity was set at 75% loss of value.

52.   This study used the Livestock Development Planning System, version 2 (LDPS-2) tool (Lalonde and Sukigara 1997) to calculate the number of gilts and young boars that would need to be retained to restock the sow and boar populations required in smallholder and intensive commercial systems nationally to supply estimated national demand levels prior to the outbreak of ASF. This tool is also deterministic. It allows the differential parameterization of livestock off-take models for different types of production system and in response to disease and no-disease scenarios. The tool was used to broadly assess costs of ASF at national level on the basis of demand prior to the outbreak and losses (to the disease or culling) of 30%–50% based on current reports and using live pig prices as reported prior to the outbreak (thereby providing a potentially conservative estimate of the costs of forgone revenue).

53.   The value of these animals was estimated on the basis of average per kilogram liveweight prices recorded in 2017 in the PRC (the year prior to the outbreak). Prices in the PRC were used as these figures could not be reliably obtained for other countries given the high levels of informal trade and pig price volatility in the region.

54.   Finally, the study considered the revenue forgone during stock replenishment through lost terminal piglets that would have been marketed as finished slaughter hogs. The study assumed that an average of two parturitions (approximately 1 year) would be lost per lost sow (based on the age profile of typical sow herds, years of productivity, and so forth). The study examined typical production figures in the two systems (commercial and smallholder) based on figures obtained from academic literature in the region and internationally. This study determined the average number of parturitions, litter sizes, number of pigs per sow per year, and normal mortality rates for terminal stock for the different systems and calculated the number of market weight pigs that failed to reach the market during restocking. The same liveweight prices were then used to approximate the revenue foregone, estimating that average profits per head ranged from 15% to 50% before and after the ASF outbreak in the PRC.

55.   **Price data.** Pig prices in the PRC from 2017 were used in regional calculations (Table A1.1). Pig and pork prices have fluctuated considerably over the past 10 years due to complex factors including policy changes and global feed prices. Moreover, due to the difference in scale of the PRC herd, and subsequent losses, and neighboring country herds, the effect of minor differences between countries is negligible, especially when considering the preliminary nature of this analysis and the assumptions made. In analyses of economic impacts within the PRC, regional price estimates from Patton (2019) were used (Table A1.2).

Table A1.1: Pig Price Data Used in Cross-country Analyses

System	Production Stage	Live Weight[a] (kg)	Price/kg ($)	Price/head ($)
Small–medium	Prewean	15	7.14	107.14
Small–medium	Grower	70	2.86	200.00
Small–medium	Sow	150	2.14	321.43
Commercial	Prewean	20	7.14	142.86
Commercial	Grower	90	2.86	257.14
Commercial	Sow	200	2.14	428.57

kg = kilogram.

[a] Estimated average live weight for the system and stage.

Sources: Food and Agriculture Organization Corporate Statistical Database. http://www.fao.org/faostat/en/#home (accessed 9 January); Nga, N. et al. 2015. Household Pork Consumption Behavior in Vietnam: Implications for Pro-Smallholder Pig Value Chain Upgrading. *International Livestock Research Institute (ILRI)*. Nairobi. Presented at the Conference on International Research on Food Security, Natural Resource Management and Rural Development. 16-18 September. Berlin, Germany; United States Department of Agriculture (USDA). 2016. China - People's Republic of: Livestock and Products Annual. GAIN Report Number: CH 16043. *Global Agricultural Information Network (GAIN)*. Washington D.C.: USDA *Foreign Agricultural Service*; USDA. 2019. Livestock and Poultry: World Markets and Trade. Foreign Agricultural Service. Washington D.C.; A. Zhang. 2019. *One Year on From the First ASF Outbreak, Where is China's Pork Industry Heading? The Pig Site.* https://www.thepigsite.com/articles/one-year-on-from-the-first-asf-outbreak-where-is-chinas-pork-industry-heading.

Table A1.2: Pig Price Data Used in within the People's Republic of China Analyses

Region/System/Production Stage	Live Weight (kg)	Price/kg (CNY)		Price/kg ($)		Price/Head (CNY)		Price/Head ($)	
		Aug 2018	Aug 2019	Aug 2018	Aug 2019	Aug 2018	Aug 2019	Aug 2018	Aug 2019
Northeast/Small—Medium									
Prewean	15	31	50	4.43	7.14	465	750	66.43	107.14
Grower	70	14	20	2.00	2.86	980	1,401	140.00	200.20
Sow	150	15	28	2.14	4.00	2,247	4,200	321.00	600.00
Northeast/Commercial									
Prewean	20	31	50	4.43	7.14	620	1,000	88.57	142.86
Grower	90	14	20	2.00	2.86	1,260	1,802	180.00	257.40
Sow	200	15	28	2.14	4.00	2,996	5,600	428.00	800.00
Central/Small—medium									
Prewean	15	31	66	4.43	9.43	465	990	66.43	141.43
Grower	70	14	23	2.00	3.29	980	1,610	140.00	230.00
Sow	150	15	28	2.14	4.00	2,247	4,200	321.00	600.00
Central/Commercial									
Prewean	20	31	66	4.43	9.43	620	1,320	88.57	188.57
Grower	90	14	23	2.00	3.29	1,260	2,070	180.00	295.71
Sow	200	15	28	2.14	4.00	2,996	5,600	428.00	800.00
Southern/Small—medium									
Prewean	15	31	58	4.43	8.29	465	870	66.43	124.29
Grower	70	14	28	2.00	4.00	980	1,960	140.00	280.00
Sow	150	15	28	2.14	4.00	2,247	4,200	321.00	600.00
Southern/Commercial									
Prewean	20	31	58	4.43	8.29	620	1,160	88.57	165.71
Grower	90	14	28	2.00	4.00	1,260	2,520	180.00	360.00
Sow	200	15	28	2.14	4.00	2,996	5,600	428.00	800.00

Table A1.2: Continued

Region/System/ Production Stage	Live Weight (kg)	Price/kg (CNY)		Price/kg ($)		Price/Head (CNY)		Price/Head ($)	
		Aug 2018	Aug 2019	Aug 2018	Aug 2019	Aug 2018	Aug 2019	Aug 2018	Aug 2019
West Central/Small—medium									
Prewean	15	29	58	4.14	8.29	435	870	62.14	124.29
Grower	70	16	26	2.29	3.71	1,120	1,820	160.00	260.00
Sow	150	15	28	2.14	4.00	2,247	4,200	321.00	600.00
West Central/Commercial									
Prewean	20	29	58	4.14	8.29	580	1,160	82.86	165.71
Grower	90	16	26	2.29	3.71	1,440	2,340	205.71	334.29
Sow	200	15	28	2.14	4.00	2,996	5,600	428.00	800.00

CNY = yuan, kg = kilogram.

Source: Patton, D. and H. Gu. 2019. Swine Fever Toll in China May Be Twice as High as Reported, Industry Insiders Say. *Reuters*. 30 June. https://www.reuters.com/article/us-china-swinefever-production-insight/swine-fever-toll-in-china-may-be-twice-as-high-as-reported-industry-insiders-say-idUSKCN1TV017.

APPENDIX 2: Parameters Used in the Livestock Development Planning System, Version 2 Herd Dynamic Model

56.   The Food and Agriculture Organization of the United Nations (1997) Livestock Development Planning System, version 2 (LDPS-2) herd dynamic model was used to estimate the number of replacement breeding animals required by the production sector to return production to pre-African swine fever outbreak levels to meet the demand for domestic pork products. Table A2 provides the value ranges used to set parameters in the LDPS-2 model.

Table A2: Production Parameters Used in the Food and Agriculture Organization of the United Nations Livestock Development Planning System, Version 2 Herd Dynamic Model

Parameter	Range
Meat production demand (t)	41,148–55,000,000
Fraction of target to be met by intensive system[a]	0.1–0.5
Distribution loss[a]	–
Female breeder mortality rate[a]	0.2–0.5
Male breeder mortality rate[a]	0.2–0.5
Female replacement mortality rate[a]	0.01–0.50
Male replacement mortality rate[a]	0.01–0.50
Slaughter stock mortality rate[a]	0.01–0.50
Year(s) in breeding herd[a]	3.0–5.0
Year(s) in replacement herd[a]	0.5–1.0
Year(s) to slaughter for slaughter stock[a]	0.5–1.0
Average live weight, breeder female[a] (t)	0.2–0.25
Average live weight, breeder male[a] (t)	0.2–0.25
Average live weight, slaughter stock[a] (t)	0.08–0.10
Dressing percentage (%)	70–75
Litters per sow per year[a]	1.8–2.2
Size of litter[a] (head)	9–12
Females per male breeder[a] (head)	25
Distribution losses, traditional systems[b]	–
Female breeder mortality rate[b]	0.2–0.5
Male breeder mortality rate[b]	0.2–0.5
Female replacement mortality rate[b]	0.01–0.50
Male replacement mortality rate[b]	0.01–0.50
Slaughter stock mortality rate[b]	0.01–0.50
Year(s) in breeding herd[b]	4–6
Year(s) in replacement herd[b]	0.8–1.2
Years to slaughter for slaughter stock[b]	0.7–0.9
Average live weight, breeder female[b] (t)	0.15–0.20
Average live weight, breeder male[b] (t)	0.17–0.23
Average live weight, slaughter stock[b] (t)	0.06–0.90

Table A2: Continued

Parameter	Range
Litters per sow per year[b]	1.5–2.0
Size of litter[b] *(head)*	8–11
Females per male breeder[b] *(head)*	12.5–20.0
Fraction of fallen animal eaten	NA

– = no data available.

t = metric ton.

[a] For intensive production systems.

[b] For traditional production systems.

Source: ADB.

APPENDIX 3: Supplementary Data: Initial Costs of Disease in the People's Republic of China and the Greater Mekong Subregion

57.   The input values used to estimate the initial costs of African swine fever on the countries analyzed using the model described in Appendix 1 are provided in Table A3. The resulting outputs are also provided.

Table A3: Initial Cost of Disease Parameters and Results

Country/System/Production Stage	Population	Mortality rate	Morbidity rate	Value, mortality ($)	Value, morbidity ($)	Morbidity (head) I = 0.3	Morbidity (head) I = 0.5	Morbidity costs ($) I = 0.3	Morbidity costs ($) I = 0.5	Morbidity (head) I = 0.3	Morbidity (head) I = 0.5	Morbidity costs ($) I = 0.3	Morbidity costs ($) I = 0.5	Initial losses ($) I = 0.3	Initial losses ($) I = 0.5
Cambodia/Small–Medium															
Prewean	606,733	0.9	0.1	107	80	163,818	273,030	17,551,455	29,252,426	18,202	30,337	1,462,621	2,437,702	19,014,077	31,690,128
Grower	539,318	0.9	0.1	200	150	145,616	242,693	29,123,191	48,538,652	16,180	26,966	2,426,933	4,044,888	31,550,124	52,583,540
Sow	202,244	0.9	0.1	107	80	54,606	91,010	17,552,001	29,253,336	6,067	10,112	1,462,667	2,437,778	19,014,66	31,691,114
Cambodia/Commercial															
Prewean	260,028	0.9	0.1	143	107	70,208	117,013	10,029,871	16,716,452	7,801	13,001	835,823	1,393,038	10,865,694	18,109,490
Grower	248,472	0.9	0.1	257	193	67,087	111,812	17,250,842	28,751,403	7,454	12,424	1,437,570	2,395,950	18,688,412	31,147,353
Sow	69,341	0.9	0.1	429	321	18,722	31,203	8,023,710	13,372,849	2,080	3,467	668,642	1,114,404	8,692,352	14,487,254
PRC/Small–medium															
Prewean	118,972,660	0.9	0.1	107	80	32,122,618	53,537,697	3,441,617,311	5,736,028,852	3,569,180	5,948,633	286,801,443	478,002,404	3,728,418,754	6,214,031,256
Grower	105,753,475	0.9	0.1	200	150	28,553,438	47,589,064	5,710,687,672	9,517,812,786	3,172,604	5,287,674	475,890,639	793,151,066	6,186,578,311	10,310,963,852
Sow	39,657,553	0.9	0.1	321	241	10,707,539	17,845,899	3,441,724,386	5,736,207,309	1,189,727	1,982,878	286,810,365	478,017,276	3,728,534,751	6,214,224,585
PRC/ Commercial															
Prewean	84,602,780	0.9	0.1	143	107	22,842,751	38,071,251	3,263,315,364	5,438,858,940	2,538,083	4,230,139	271,942,947	453,238,245	3,535,258,311	5,892,097,185
Grower	74,027,433	0.9	0.1	257	193	19,987,407	33,312,345	5,139,561,800	8,565,936,333	2,220,823	3,701,372	428,296,817	713,828,028	5,567,858,616	9,279,764,360
Sow	17,625,579	0.9	0.1	429	321	4,758,906	7,931,511	2,039,524,514	3,399,207,523	528,767	881,279	169,960,376	283,267,294	2,209,484,890	3,682,474,816
Lao PDR/Small–medium															
Prewean	1,218,735	0.9	0.1	107	80	329,058	548,431	35,255,322	58,758,871	36,562	60,937	2,937,944	4,896,573	38,193,266	63,655,443
Grower	1,083,320	0.9	0.1	200	150	292,496	487,494	58,499,280	97,498,800	32,500	54,166	4,874,940	8,124,900	63,374,220	105,623,700
Sow	406,245	0.9	0.1	321	241	109,686	182,810	35,256,419	58,760,699	12,187	20,312	2,938,035	4,896,725	38,194,454	63,657,424

Table A3: Continued

Country/System/Production Stage	Population	Mortality rate	Morbidity rate	Value, mortality ($)	Value, morbidity ($)	Mortality (head)	Mortality costs ($)	Mortality (head)	Mortality costs ($)	Morbidity (head)	Morbidity (head)	Morbidity costs ($)	Morbidity costs ($)	Morbidity costs ($)	Initial losses ($)
Lao PDR/Commercial															
Prewean	522,315	0.9	0.1	143	107	141,025	20,146,839	235,042	33,578,064	15,669	26,116	1,678,903	2,798,172	21,825,742	36,376,236
Grower	499,101	0.9	0.1	257	193	134,757	34,651,484	224,595	57,752,474	14,973	24,955	2,887,624	4,812,706	37,539,108	62,565,180
Sow	139,284	0.9	0.1	429	321	37,607	16,117,095	62,678	26,861,825	4,179	6,964	1,343,091	2,238,485	17,460,186	29,100,310
Myanmar/Small–medium															
Prewean	6,479,733	0.9	0.1	107	80	1,749,528	187,444,406	2,915,880	312,407,344	194,392	323,987	15,620,367	26,033,945	203,064,774	338,441,289
Grower	5,759,762	0.9	0.1	200	150	1,555,136	311,027,161	2,591,893	518,378,602	172,793	287,988	25,918,930	43,198,217	336,946,091	561,576,818
Sow	2,159,911	0.9	0.1	321	241	583,176	187,450,238	971,960	312,417,064	64,797	107,996	15,620,853	26,034,755	203,071,091	338,451,819
Myanmar/Commercial															
Prewean	1,619,933	0.9	0.1	143	107	437,382	62,484,385	728,970	104,140,641	48,598	80,997	5,207,032	8,678,387	67,691,417	112,819,028
Grower	1,547,936	0.9	0.1	257	193	417,943	107,469,798	696,571	179,116,330	46,438	77,397	8,955,817	14,926,361	116,425,615	194,042,691
Sow	431,982	0.9	0.1	429	321	116,635	49,986,341	194,392	83,310,569	12,959	21,599	4,165,528	6,942,547	54,151,870	90,253,116
Viet Nam/Small–medium															
Prewean	8,633,123	0.9	0.1	107	80	2,330,943	249,737,249	3,884,905	416,228,749	258,994	431,656	20,811,437	34,685,729	270,548,687	450,914,478
Grower	7,673,887	0.9	0.1	200	150	2,071,949	414,389,894	3,453,249	690,649,823	230,217	383,694	34,532,491	57,554,152	448,922,385	748,203,975
Sow	2,877,708	0.9	0.1	321	241	776,981	249,745,019	1,294,968	416,241,699	86,331	143,885	20,812,085	34,686,808	270,557,104	450,928,507
Viet Nam/Commercial															
Prewean	3,946,570	0.9	0.1	143	107	1,065,574	152,227,903	1,775,957	253,713,172	118,397	197,329	12,685,659	21,142,764	164,913,562	274,855,937
Grower	3,453,249	0.9	0.1	257	193	932,377	239,751,489	1,553,962	399,585,815	103,597	172,662	19,979,291	33,298,818	259,730,780	432,884,633
Sow	822,202	0.9	0.1	429	321	221,995	95,140,220	369,991	158,567,033	24,666	41,110	7,928,352	13,213,919	103,068,571	171,780,952

I = infection rate/attack rate (proportion of the pig population that becomes infected and/or are culled during disease response efforts), Lao PDR = Lao People's Democratic Republic, PRC = People's Republic of China.

Source: ADB.

APPENDIX 4: Critical Transboundary Animal Diseases, Foodborne Pathogens, and Non-Foodborne Zoonoses

58.   This paper considers the 2018 outbreak of African swine fever in East Asia specifically, however, as referred to in the discussion section of the paper, there are numerous other diseases that impact animal producers and, at times, human health directly in the form of zoonoses. Table A4 lists some of the most important hazards to animal and human health associated with animal production in Asia, particularly.

Table A4: Examples of Terrestrial Animal Production Associated Hazards in the People's Republic of China and the Greater Mekong Subregion

Hazard Category	Potential Hazards
Transboundary Animal Diseases	**Endemic or frequent outbreaks.** Foot-and-mouth disease, classical swine fever, porcine reproductive and respiratory syndrome, highly pathogenic avian influenza viruses (HPAI) (e.g., H5N1, H7N9, H1N1), Newcastle disease
	Emerging or high risk. African swine fever, other HPAI and influenza viruses, pest de petit ruminants
Foodborne Pathogens	*Salmonella* spp, enterotoxigenic *E. coli*, shiga-toxin producing *E. coli, Campylobacter* spp., *Toxoplasma gondii, Trichinella spiralis, Taenia solium,* various other parasites including other nematodes, cestodes and trematodes (flukes, *Fasciola* spp., etc.)
Non-foodborne Zoonoses	HPAI, *Mycobacterium bovis* (bovine tuberculosis), *Bacillus anthracis* (anthrax), *Leptospira* spp. (leptospirosis), *Coxiella burnetti* (Q fever), *Brucella* spp. (brucellosis), *Streptococcus suis*
Chemical Hazards	**Veterinary drug residues.** Primarily antimicrobial residues and coccidiostats and other parasiticides, growth hormones, and other growth promoters

Source: ADB.

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Evaluating Losses Associated with African Swine Fever in the People's Republic of China and Neighboring Countries

This paper aims to assist policymakers in assessing the scale of the impact of African swine fever (ASF) on the People's Republic of China (PRC) and Southeast Asia. The results of the study indicate that ASF's direct costs on the PRC—which produces about half of the world's pigs—and neighboring countries could be as much as $130 billion. Much of the burden is falling disproportionately on smallholders, threatening increases in poverty, vulnerability, and food insecurity. ASF has driven up the prices of pork and other food supplies, and it also has had substantial effects on human health, trade, climate change resilience, and local environments.

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