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How China's African Swine Fever Outbreaks Affected Global Pork Markets

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Abstract

After reaching China from Europe in 2018, the African swine fever (ASF) virus spread throughout the country, dramatically reducing China's pork supplies. This report investigates the impacts on China's pork market that resulted from the virus and how China's increased demand for imported pork affected markets for pork-exporting countries. China's swine herd experienced a 30-month cycle of decline and recovery, as the country lost an estimated 27.9 million metric tons of its pork output. Pork prices in China more than doubled despite a surge of pork exports from the European Union, United States, Canada, Brazil, and other countries. Pork exports to China prompted smaller price increases in exporting countries' pork markets. As China's domestic pork supplies recovered about 3 years after the first ASF outbreaks, Chinese pork prices declined to near their pre-ASF level. U.S. pork exports to China declined but remained above their pre-ASF volume. Volatility in China's pork market is an ongoing source of uncertainty for exporters despite the rebound in China's production.

Keywords: pork, hogs, African swine fever, China, livestock disease, exports, imports, prices

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About the Authors

Fred Gale, Jennifer Kee, and Joshua Huang are agricultural economists with the USDA, Economic Research Service.

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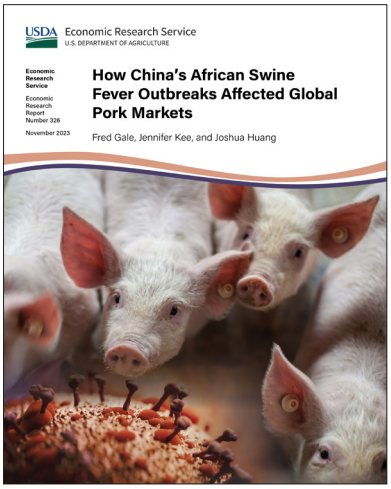


What Is the Issue?

Animal disease outbreaks can cause unexpected changes in supply and demand for meat and other livestock products. These changes can result in price fluctuations and disruptions in foreign trade that create uncertainty in international markets. Diseases that spread across national boundaries and result in the culling of large numbers of animals in major producing countries are especially disruptive. This is what happened when African swine fever (ASF) spread from Europe to China in 2018—one of the largest animal disease incidents ever. The outbreak reduced China's pork supply, and Chinese pork prices more than doubled to reach record levels. As China accounts for nearly half of the pork produced and consumed in the world, this report investigates the degree to which China's reduced pork supply affected pork-exporting countries.

What Did the Study Find?

- The ASF virus moved from Europe to China in August 2018, then spread rapidly throughout the country. The virus impacted China's pork supply more than indicated by the number of officially reported outbreaks.
- Following China's first ASF cases, its swine herd went through a 30-month cycle of decline and recovery from the third quarter of 2018 (Q3) to 2021 (Q1).
- China lost an estimated 27.9 million metric tons of its pork production during the 30-month cycle. China imported a record volume of pork during those months, but the imports replaced only one-fifth of lost production. Thus, China experienced shortfalls in pork supplies for about 18 months, concentrated during the second half of 2019 and most of 2020.
- Increases in pork prices lagged the spread of the disease. Pork prices in China more than doubled, with most of the increase occurring about a year after the initial outbreaks. Pork prices remained at a high level for 14 months and then fell rapidly during 2021. Pork prices returned to near their pre-ASF level about 38 months after the first outbreaks.
- Pork exports to China surged during 2019–20. China accounted for 45 percent of world pork imports in 2020.

- A total of 31 countries exported pork to China, but the European Union accounted for 58 percent of the exports. The United States was the second-leading pork exporter to China, with a 15 percent share, despite trade tensions that coincided with China's ASF outbreaks.
- During the 14-month peak in China's import demand, the share of pork exported to China increased for top pork-exporting countries. Sales of higher value cuts grew fastest.
- Impacts on pork markets outside of China were relatively modest. For example, increases in pork prices in three leading pork exporting countries (the United States, Germany, and Spain) were relatively brief and much smaller in magnitude than price increases in China.
- Volatility in China's pork market is an ongoing source of uncertainty for exporters despite the rebound in China's production.

How Was the Study Conducted?

The study analyzes officially reported ASF outbreaks in China using data from China's Ministry of Agriculture and Rural Affairs and United Nation's World Organization for Animal Health. The report authors analyzed officially reported outbreaks to track the temporal and geographic spread of the disease. The study consulted national supply statistics, price data, official announcements, scientific articles, and private industry reports to provide a comprehensive assessment of the economic impacts of African swine fever in China. The study also gauges the impacts on pork-exporting countries using Chinese customs data.

How China's African Swine Fever Outbreaks Affected Global Pork Markets

Introduction

Animal diseases are one of the chief sources of uncertainty in global markets for meat and other livestock products. This report reviews the economic impacts of African swine fever (ASF) in China during 2018–21, one of the largest animal disease incidents ever.

ASF causes fever, hemorrhaging, and death in swine that are infected with the virus. The disease is not transmissible to humans, but it spreads rapidly among both feral and domestic swine. ASF can severely impact pork supplies due to the mortality of animals and aggressive depopulation of herds, which is the only effective way to halt the disease spread.

Since China produces and consumes nearly half the world's pork, the spread of the ASF virus to China in 2018 was an important development in the global pork market. Previous studies (Mason-D'Croz et al., 2020; Hu & Ge, 2020; You et al., 2021) predicted large economic impacts from the ASF outbreak in China. Haley and Gale (2020) reported declining pork production in China and the growth in U.S. pork exports due to the ASF outbreaks.

This report examines data from the Chinese Government to assess the spread of the disease in China, impacts on pork supplies in China, the role of imports in replacing pork supplies lost to the virus outbreak, the rise of pork prices, and impacts on pork markets in exporting countries. This study also shows the reversal of these economic impacts after pork supplies rebounded. ASF was never eliminated from China—it is now endemic in the country—but Chinese officials claimed the virus was "under control" less than 6 months after the first cases were reported.

The Spread of African Swine Fever, 2005–22

Global Spread of African Swine Fever

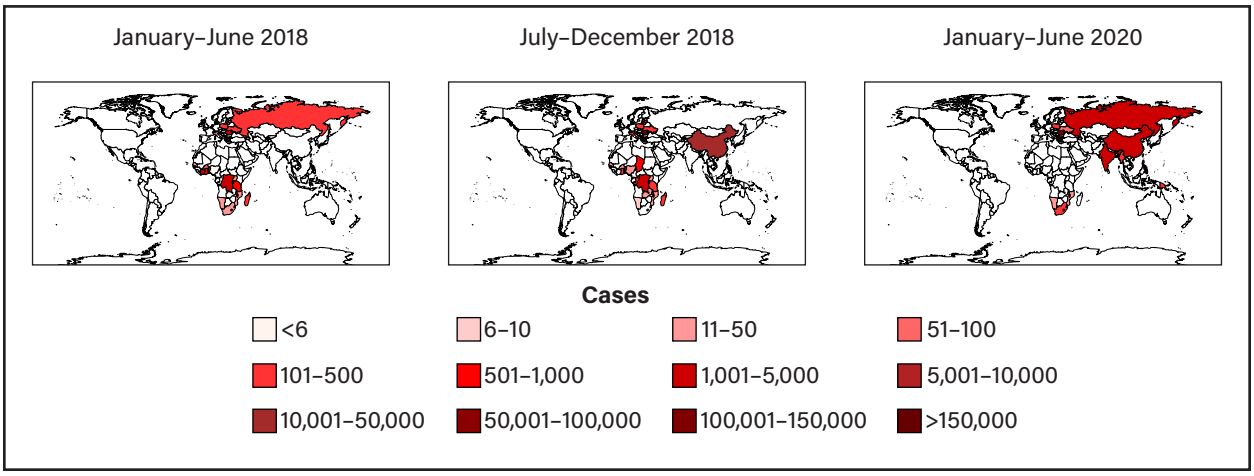
The ASF virus first emerged in Africa during the 1920s. The virus spread to Europe and Latin America during the 1960s. ASF was eradicated in those regions (except on Italy's island of Sardinia) by the 1990s. In 2007, ASF appeared in the country of Georgia and spread to neighboring countries of the Caucasus region, to Russia, then to Eastern and Western Europe (Mighell & Ward, 2021). The spread of the virus in Europe set the stage for the spread of ASF to China in August 2018—the first time ASF reached East Asia. ASF then spread to most neighboring countries in Asia by 2019.

Figure 1 summarizes the geographic spread of ASF to China and other countries, using data from the World Organization for Animal Health (WOAH). See box, "Animal Disease Reporting to the World Organization for Animal Health."[1]

[1] The World Organization for Animal Health (WOAH) was often known by the acronym OIE (Office International des Épizooties) until the current acronym was adopted in 2022.

During the first half of 2018, ASF cases affecting individual animals were concentrated in Africa, Europe, and Russia. During the second half of 2018, more cases were reported in Russia, and the virus spread to China. By January–June 2020, ASF cases were reported in southern Africa, Eastern Europe, Russia, China, and many Asian countries.

Figure 1
Geographic distribution of African swine fever outbreaks, January 2018–June 2020



Source: USDA, Economic Research Service analysis of data from the World Organization for Animal Health (WOAH).

Animal Disease Reporting to the World Organization for Animal Health

This report summarizes the spread of African swine fever using reports of outbreaks from the World Organization for Animal Health (WOAH). Provisions of the WOAH Terrestrial Animal Health Code call for an outbreak of a notifiable animal disease or infection to be brought to the attention of a member country's governmental veterinary authority and reported to WOAH headquarters. A disease can be detected by clinical manifestation or by diagnostic tests in domestic and/or wild species.

Definitions of key terms used in WOAH notifications summarized in this report are as follows:

- Cases: number of animals infected (with or without clinical signs) plus animals that died from the disease
- Epidemiological unit: a group of animals in a defined epidemiological relationship with the same likelihood of exposure to a pathogen, usually a herd or a village, sometimes a single animal
- Outbreak: the occurrence of one or more cases in an epidemiological unit
- Susceptible animals: the number of animals present in an ongoing active outbreak
- Culled: number of animals culled and destroyed by incineration or burning; does not include animals that died from the disease or were slaughtered

Charts in figure 2 display the geographic spread of ASF by showing the number of cases reported to the WOAH during 2005–22 (in 6-month intervals) to show how the virus spread across the continents of Africa, Europe, China, other Asian countries, Oceania, and the Americas. Reports of ASF were made by 68 countries during these years. Each chart highlights 2018, when the first ASF outbreak was reported in China, for

reference. The scale of the vertical axis differs by continent due to the wide differences in number of cases reported. The number of reported cases for peak periods is shown.

ASF outbreaks were reported in Africa throughout 2005–22, but a surge of 1.75 million cases (sickened animals) in Africa was reported in the first half of 2011. Europe began experiencing a small surge of over 8,800 cases in 2008, and a surge of nearly 130,000 was reported in the second half of 2014. European cases were in the tens of thousands per-6-month period during 2016–18 before surging to more than 3 million in the second half of 2018. Romania and Russia accounted for most of the cases, over 340,000 during July–December 2018. European outbreaks during 2017 were reported in Belarus, the Czech Republic, Lithuania, Moldova, Poland, Romania, Russia, and Ukraine (United Nations Food and Agriculture Organization, 2018). Another European spike of 4.9 million cases was reported in the second half of 2021, particularly in Romania.

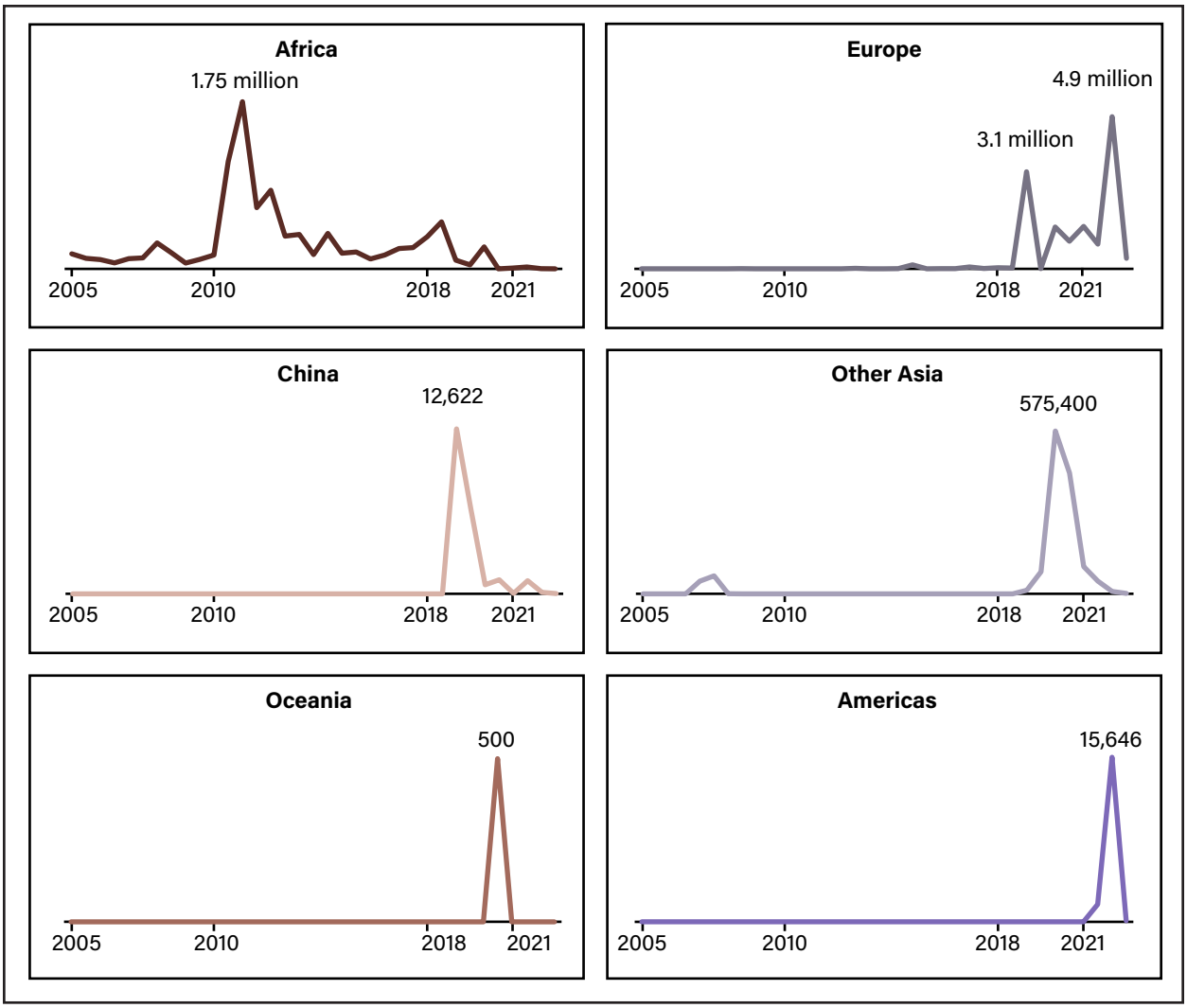
China's reported spike in cases during 2018–19 was relatively few in number, and the outbreak was brief compared with those of Africa and Europe.[2] China's cases surged to 12,622 animals in July–December 2018 when the virus first entered the country. Cases then fell by half to 6,495 in the first 6 months of 2019 and dropped to 690 in the second half of that year. The resurgence of cases to roughly 1,000 during January–June 2020 (and again during January–June 2021) was relatively small compared with cases in Africa and Europe. Just 16 Chinese cases were reported in the first half of 2022.

During 2019, a spike in Asian cases occurred as the virus spread to Hong Kong, Vietnam, Indonesia, Laos, Myanmar, Philippines, Cambodia, Mongolia, North Korea, South Korea, and Timor-Leste. India reported its first cases of ASF in 2020. Indonesia had the highest number of cases, 71,559 in 2020, and neighboring Malaysia discovered its first cases in 2021. Thailand reported its first cases in 2021. Hong Kong slaughterhouses detected infected animals imported from China in 2019, and infected wild boars were discovered in Hong Kong in 2021 and 2022. Mighell and Ward's (2021) analysis of WOAH cases in Asia found that China's was the first outbreak, followed by Vietnam and Laos before spreading to other countries. Le et al. (2019) confirmed that ASF virus samples gathered from a January 2019 outbreak in Vietnam matched those from China and Georgia. Neither Japan nor Taiwan reported local ASF cases, but a series of infected carcasses washed ashore on Taiwan's coastline from 2019 through 2022 (Linden, 2022b).

The small number of outbreaks detected in Oceania were reported in Papua New Guinea. ASF was reported in the Dominican Republic and Haiti during 2021—the only cases in the Americas. The appearance of the disease in these Caribbean countries 800 miles from Florida raised concerns that the virus could spread to the United States. USDA's Animal and Plant Health Inspection Service conducted surveillance in those countries, sought to eradicate feral swine populations in Puerto Rico and the U.S. Virgin Islands, and sponsored activities to raise awareness of the threat of ASF reaching the United States (USDA, Animal and Plant Health Inspection Service, 2022).

[2] This report explains below that China's officially reported outbreaks are only a fraction of the actual occurrences of African swine fever. Mighell and Ward's (2021) analysis of reported ASF outbreaks showed a much higher concentration in Vietnam than in China, which does not appear to reflect the actual incidence of the disease.

Figure 2
Peak number of African swine fever cases, semi-annual totals by geographic region, 2005–22



Note: The charts show 6-month case totals that were reported to the World Organization for Animal Health (WOAH); the vertical axis scale differs by region.

Source: USDA, Economic Research Service analysis of data from WOAH.

Spread of ASF in China

On August 1, 2018, China's Ministry of Agriculture and Rural Affairs (MARA) reported its first ASF outbreak on a small farm on the outskirts of Shenyang, the capital of Liaoning Province in northeastern China. Four other reports of ASF during August 2018 were scattered over other Chinese provinces. One reported case was at a slaughterhouse in Zhengzhou, capital of Henan Province in central China. The slaughterhouse had acquired the pigs from Heilongjiang Province (near the Russian border) and transported the pigs by truck hundreds of miles to the facility. Other August cases were reported in three provinces of eastern and central China, separated by hundreds of miles. Most cases were found on farms with a few hundred swine, but one outbreak was on a large farm holding 4,647 head.

An official from China's Animal Disease Control Center pronounced ASF as "generally under control" in January 2019, 5 months after the initial cases were reported (Ministry of Agriculture and Rural Affairs (MARA), 2019a). However, cases were reported in new provinces during the first 4 months of 2019, indi-

cating the disease continued to spread geographically. By April 2019 (8 months after the first reported outbreak), the virus had been reported in all provinces, including the remote western regions of Xinjiang and Tibet and the island province of Hainan (Gao et al., 2021). ASF had spread throughout the country when China's first large Coronavirus (COVID-19) outbreaks and lockdowns began in 2020.

WOAH reports of ASF by China showed a smaller number of more than 750,000 swine culled and disposed of from 2018 to 2022—15,420 deaths and 22,036 cases (table 1). WOAH reports show the largest number of outbreaks by each measure were reported during July–December 2018, including 9,379 deaths, 12,622 sick animals, 357,934 susceptible animals, and 558,396 culled animals. Reported outbreaks declined during successive 6-month periods, with modest rebounds evident during January–June 2020 and the same period in 2021. Culls fell to 164,748 in January–June 2019, 4,580 in the second half of 2019, rose to 22,586 in January–December 2020, fell to 238 in the second half of that year, and rose to 42,86 in January–June 2021. By 2022, only 16 deaths and 268 culls were reported in China.

Table 1
African swine fever deaths, cases, susceptible, and culled swine in China, 2018–22

		Deaths	Cases	Susceptible swine	Culled and disposed
Year	Months	Number			
2018	July–Dec.	9,379	12,622	357,934	558,396
2019	Jan.–June	3,642	6,495	134,946	164,748
	July–Dec.	484	690	2,774	4,580
2020	Jan.–June	860	1,066	12,153	22,586
	July–Dec.	10	32	129	238
2021	Jan.–June	915	1,000	3,058	4,286
	July–Dec.	114	115	1,871	3,514
2022	Jan.–June	16	16	150	268
Total		**15,420**	**22,036**	**513,015**	**758,616**

Source: USDA, Economic Research Service based on data from the World Animal Health Organization web site.

Underreported Outbreaks

Official reports appear to have greatly understated the extent of African swine fever (ASF) outbreaks in China. While failure to report and concealment of disease outbreaks are concerns in animal disease control worldwide, several features of China's swine industry increased the complexity of controlling ASF in China.

- Monitoring farms is difficult since China had 31 million farms producing less than 500 swine annually in 2018, according to data reported by China's Ministry of Agriculture and Rural Affairs *Animal Husbandry and Veterinary Yearbook*. Most of these farms had contact only with rural veterinary practitioners, and reliable information about ASF was scarce as the virus spread rapidly across the country.

"Underreported Outbreaks" continued on next page ►

◄ "Underreported Outbreaks" continued from previous page

- Animal disease is a sensitive subject in China—animal diseases were considered a state secret until 2003 (Zhang, 2021). Lingering sensitivity is reflected by directives issued to propaganda departments to "scientifically guide public opinion" about ASF outbreaks (China Government Net, 2019) to control information about the epidemic.
- Local authorities had incentives to conceal ASF outbreaks in order to avoid damaging their reputation with higher level authorities or to avoid paying compensation to farmers for culling diseased swine.

Chinese news media reporting on the country's first appearance of ASF in Liaoning Province during August 2018 revealed that 22 ASF-positive samples (out of 35.5 million samples taken from swine in Liaoning) were discovered in 3 districts on the northern, eastern, and southern outskirts of the densely populated Shenyang urban area (China News Net, 2018). Only one ASF outbreak on a farm in the northern district was officially reported in the province that month.

The investigation of the first Liaoning outbreaks suggested the virus may have been circulating in northeastern China at least 5 months before the first case was reported. According to *China Youth Daily Online* (2018), the infected farm north of Shenyang that was officially reported had purchased pigs a month earlier (on July 5) from a farm in an eastern Shenyang district, where tests of manure confirmed the presence of ASF. Police learned that a farmer had purchased infected piglets in March from a farm in the neighboring province of Jilin. The Jilin farm had sold other diseased animals to itinerant traders. China did not issue reports of ASF in Jilin Province until September, and those outbreaks were in other parts of the province.

Chinese news media reported that some local and provincial officials refused to report ASF outbreaks for at least two main reasons (Caixin, 2019). Some officials refused to report outbreaks to avoid damaging their reputation with higher level authorities. Many local officials were accused of concealing outbreaks to avoid paying compensation to farmers for culling swine. With compensation for culling uncertain, farmers concerned about property loss often sold off entire herds—even potentially infected pigs—to traders or slaughter facilities when the farmers heard rumors of nearby disease outbreaks (Guo et al., 2023). Small farmers with crude barns, lax disinfection procedures, and other vulnerabilities to disease reportedly quit raising pigs entirely, and many cases may not have been captured by the culling and mortality data (You et al., 2021).

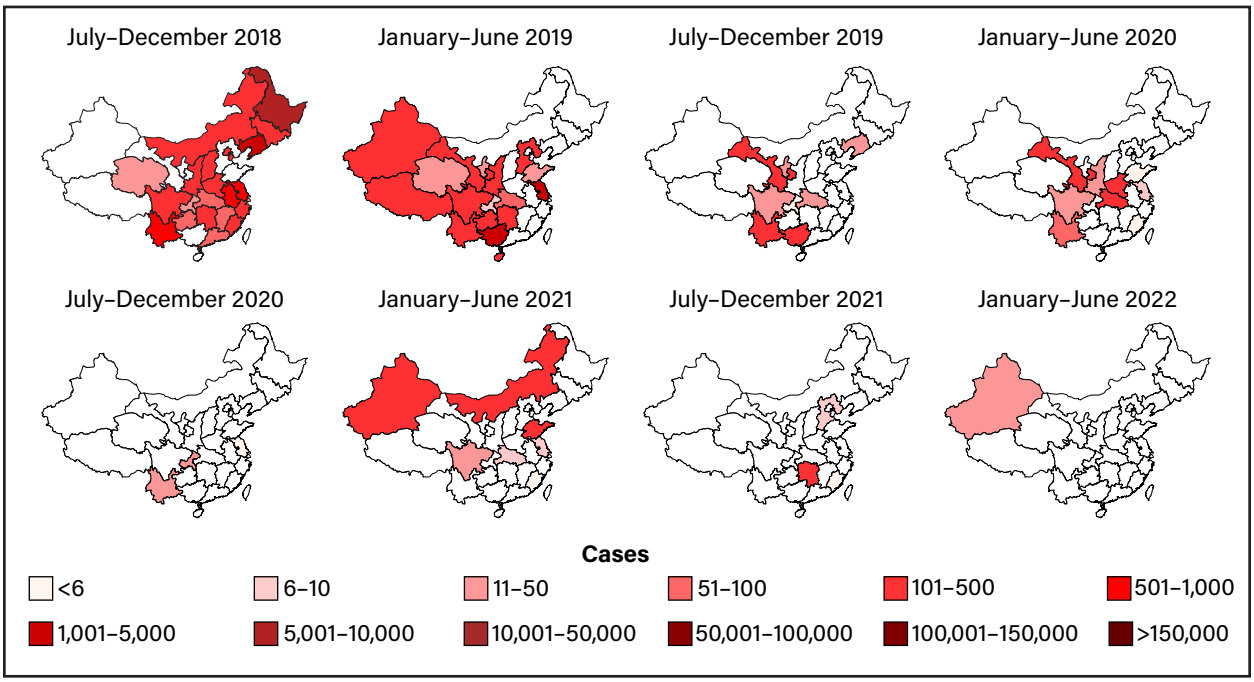
Two major hog-producing provinces each officially reported only one ASF outbreak, even though there were reports of large outbreaks in those areas. Agricultural data for reported decreases in each province's swine populations exceeded 20 percent in 2019. Hebei Province officially reported its only case after the owner of a farm complained publicly that local officials had refused to acknowledge his loss of thousands of pigs to the virus (Patton, 2019; Reuters, 2021a). In Shandong Province, only one outbreak was reported, but the Shandong Province Animal Husbandry and Veterinary Bureau (2019) described outbreaks in locations where no outbreak was officially reported. Caixin (2019) cited a March 2019 report from Shandong Province showing that the province's breeding herd had declined 41 percent from the previous year, indicating that ASF was more widespread than the single outbreak reported by the province. Caixin (2019) interviewed several farmers in Guangdong and Shandong Provinces who reported to local authorities that they lost thousands of pigs that tested positive for ASF, but the local governments never reported those cases.

Official reporting of cases in China appeared to reflect the changing focus of surveillance activities. For example, no wild boar cases were reported until a campaign was launched to heighten surveillance of wild boars (Gao et al., 2021). Most ASF cases reported after July 2019 were discovered on trucks or among animals transported to a farm from elsewhere, apparently reflecting a campaign to crack down on illegal transportation at that time (Gao et al., 2021).

Outbreaks reported by WOAH showed that the virus spread across different regions of China from 2018 to 2022 (figure 3). While cases during the peak months in the second half of 2018 were concentrated in north-eastern provinces, most regions of the country had ASF infections. Outbreaks spread to western and south-western provinces during the first 6 months of 2019. Reported outbreaks were more geographically confined to central regions during the second half of 2019 and the first half of 2020. Only 32 cases were reported during the second half of 2020 before a resurgence occurred in the first half of 2021. Then, only 131 cases were reported in the second half of 2021 and 2022.

ASF continued to affect China's swine industry, despite declining official reports of ASF. Occurrences were reported by the hog industry every winter from 2020 to 2022. For example, in 2023, the country's third-largest swine producer, New Hope Group, attributed an increase in its hog production cost to an outbreak of ASF in its swine herd in late 2022 (China Feed Information Net, 2023). In March 2023, a debate among analysts and company representatives over a securities firm's report of a resurgence in ASF infections revealed that at least a moderate increase in infections had occurred in multiple provinces although no cases were reported by WOAH (*National Business Daily*, 2023).

Figure 3
African swine fever cases across provinces in China, 2018–22



Note: "Cases" refers to sickened swine.

Source: USDA, Economic Research Service compilation of data from World Organisation for Animal Health.

African Swine Fever Spread Rapidly Through China's Swine Industry

In China, ASF spread mainly among domestic swine on farms, transportation equipment, and slaughter facilities. About 50 of 180 notices of ASF outbreaks posted on the Ministry of Agriculture and Rural Affairs' website from 2018 to 2022 were on small-scale/backyard farms holding fewer than 100 swine, including 2 farms with just a single animal. Another 30 outbreaks were reported on farms and cooperatives holding 1,000 to 70,000 animals. Other reported outbreaks were on mid-sized farms, at slaughter facilities, on trucks, and in wild boar.

Wild boar played a smaller role in spreading ASF in China than in Western European countries like Belgium, Poland, and Germany. A study by China's Animal Health and Epidemiology Center (Gao et al., 2021) found that most outbreaks reported as of April 2020 were on farms, while 17 outbreaks were discovered on trucks carrying swine, and 5 outbreaks were reported in slaughterhouses. The Ministry of Agriculture and Rural Affairs reported only six infections detected in wild boar.[3] Two of the infections were on farms raising the boar commercially. Chen and Ward (2022) found that only a few Chinese articles mentioned ticks or wild pigs as a means of transmitting ASF to domestic pigs.

Even the largest farms saw declines in production after the initial spread of the virus in 2018–19. Investor materials issued by one of China's top hog-producing companies reported that its sales volume declined from 22 million head to 9.5 million head between 2018 and 2020, and the reproductive performance of its sows had deteriorated (Wens Foodstuff, 2019; Wens Foodstuff, 2021). Other sources indicated that swine inventories on breeding farms—including those raising purebred grandparent and great-grandparent stock—were reduced by ASF outbreaks (New Hope Liuhe, 2021a; National Animal Husbandry Station (NAHS), 2022a; NAHS, 2022b).[4]

Factors Contributing to the Rapid Spread of African Swine Fever in China

Gao et al.'s (2021) investigation attributed the largest number of ASF outbreaks to swill-feeding of infected waste from restaurants and other food. The virus was spread by infected pork contained in the swill, but the investigation did not seem to consider how the virus spread to the farms that produced the infected waste. A secondary cause the inspectors identified was transmission by trucks and personnel entering farms. Gao et al. (2021) noted about half of the infections reported after July 2019 were attributed to the transportation of animals.[5] Chen and Ward's (2022) review of news, veterinary reports, and other documents found that long-distance transport, swill-feeding, and contamination of trucks were the most often cited risk factors in studies of ASF spread in China. Lack of access to veterinary services in remote areas was mentioned less often.

MARA (2018) cited the falsification of inspection certificates by corrupt veterinarians as one of the factors promoting the spread of the virus. Small-scale farmers' sale and slaughter of infected animals may have spread the disease to transportation equipment and slaughterhouses. Caixin (2019) pointed to several factors that contributed to the spread of the disease: neglect of rural veterinary services; farmers delivering entire herds to slaughterhouses due to disease rumors (infected animals could have spread the disease to trucks, personnel, roads, and slaughter facilities); and transmission by infected pigs and contaminated equipment when pigs were transported long distances, a practice encouraged by an environmental initiative to shift swine production to northern regions during the years before the ASF outbreaks.

Chinese hog-farming companies revealed that new strains of the ASF virus affected hog production in northern provinces during late 2020, late 2021, early 2022, and late 2022 (New Hope Liuhe, 2021b; New Hope Liuhe, 2022; Tech-bank Food, 2022; China Swine Science Conference, 2022; China Feed Information Net, 2023). Surveillance studies found that less lethal but more contagious ASF virus variants became prevalent in the northern provinces of Hebei, Shandong, and Henan during 2020 and 2021. The studies found that newer strains had a longer incubation period, less distinct clinical symptoms, and caused chronic ASF infections (Sun et al., 2021a; Sun et al., 2021b). Some of the low-virulent strains were found to lack genes deleted to create vaccines developed by two Chinese institutes (see box, "ASF Vaccines Still in Development"). A large hog-producing company said these strains reduced sow reproductive performance (Ma, 2021). Some

[3] The genotype of the virus discovered in the first infected wild boar differed from the genotype in the commercial herd.

[4] In contrast, African swine fever mainly affected small farms in Thailand but had little impact on large pork-producing Thai companies, according to Ter Beek (2023).

[5] Officials apparently did not investigate the source of infected pigs found on trucks.

experts suggested that other low-virulent strains found in the field might be related to imported vaccine candidates from European sources due to a striking degree of genetic similarity with strains isolated in Portugal in the 1960s that differed from the first strains discovered in China in 2018 (Rock, 2021a; Sun et al., 2021b). The new strains induced producers to adjust their detection/testing programs and strengthen biosecurity measures (China Swine Science Conference (CSSC), 2022; Wang & Chen, 2022).

China's Prevention Activities in Response to African Swine Fever

The authors' examination of various documents and reports found that officials in China anticipated the risk of ASF spreading to their country years before the virus arrived.

- In 2012, 10 Chinese Government agencies issued a document warning that ASF might enter China and called for surveillance in provinces bordering Russia.
- In 2016, China's Ministry of Agriculture and Rural Affairs released a 5-year plan for the swine industry that warned of ASF risk.
- In April 2017, a bulletin issued by Chinese authorities put animal disease inspectors and customs officials on high alert to prevent entry of ASF (MARA, 2017). The bulletin was released a month after an outbreak in Irkutsk, Russia, about 300 kilometers from Mongolia and 1,000 kilometers from China's border (United Nations Food and Agriculture Organization [FAO], 2018).
- In 2018, the United Nations Food and Agriculture Organization (FAO) warned that the spread of ASF to China would have "devastating consequences" and identified the northeastern province of Heilongjiang on the Russian border as the region most at risk (FAO, 2018).
- In 2018, Chinese agricultural officials held a series of ASF technical trainings and surveillance activities in border areas, including surveillance of wild boar and emergency response drills along the Russia border 3 months before the first Chinese case was reported.

Before ASF reached China in 2018, China banned pork from 21 countries that had reported ASF outbreaks. Countries included Georgia, Armenia, Italy, Malta, Baltic countries, Russia and most of its neighbors, some countries in Central and Eastern Europe, Belgium in Western Europe, and Botswana, Madagascar, Senegal, and Ghana in Africa (see appendix table 1). China's list of banned countries due to ASF grew to 46 in 2022 as the virus spread to new regions. During 2019–21, China banned pork imports from most neighboring countries in Asia where the virus had spread. China blocked pork from several additional European countries as well. By 2022, China had banned pork imports from 21 countries in Europe, 17 Asian countries, Papua New Guinea, the Dominican Republic, Haiti, and all of Africa.

When ASF reached China, official reports of outbreaks stated that all animals within a certain radius were culled, and the area was sealed off. The Ministry of Agriculture and Rural Affairs announced in 2019 that farmers would be compensated 1,200 yuan per head for culled pigs, but localities could set a higher or lower rate (*Beijing Youth News*, 2019). Funding for the compensation was to be shared by central, provincial, and local governments, but many outbreaks were not acknowledged by local authorities because the authorities claimed to have insufficient funds to pay their share (Caixin, 2019; Guo et al., 2023). Thus, many farmers received no compensation for culling animals, a problem reflected in the Ministry of Agriculture and Rural Affairs' instructions to ensure compensation was paid.

Some large farms experimented with a partial culling strategy (also known as "precise detection and removal" or "tooth extraction" in China) to avoid complete depopulation of their herds when the virus was detected. MARA (2020b) officially permitted/legalized this practice. One U.S. veterinarian said the practice had been successful (Hess, 2020). Other sources said success depended on each producer's implementation and that

effectiveness was diminished against new strains (New Hope Liuhe, 2021a; Wang & Chen, 2022). A study of partial culling during Vietnam's ASF outbreak found that farms retained about half of their animals, on average, but the study could not assess whether the virus was eliminated from farms by partial culls since surviving animals were not tested (Nga et al., 2022).

African Swine Fever Vaccine Still In Development

Numerous studies address the possibility of developing African swine fever (ASF) vaccines (Rock, 2021b; Lacasta et al., 2015; King et al., 2011; Leitão et al., 2001; Hamdy and Dardiri, 1984), but vaccine development has been impeded by gaps in knowledge about ASF infection, immune systems, ASF strain variations, and its proteins (Rock, 2021b; Ackerman, 2022).

A live attenuated vaccine developed by China's Harbin Veterinary Research Institute was the first Chinese ASF vaccine approved for commercial clinical trials in 2020. A live attenuated vaccine uses a weakened live virus produced by deleting one or more virulent genes of a virus. This vaccine deleted several genes from the ASF virus (Chen et al., 2020).

A Military Veterinary Institute in Changchun developed an inactivated vaccine using the same gene-deletion approach (Zhang et al., 2019) and applied for clinical trials in June 2022. Other Chinese research institutions and companies worked on vaccines, but no clinical trials were publicly announced (Cheng & Meng, 2022).

In 2019, researchers at the Harbin Veterinary Research Institute suggested the trials would take 1.5 years (Feedtrade, 2019). In 2021, China's Ministry of Agriculture and Rural Affairs shortened the posttrial new drug registration process from more than 1 year to 2 months in order to expedite the availability of new vaccines. However, no progress on the Harbin vaccine trials had been disclosed as of February 2023, despite positive results from initial trials conducted in several provinces that were presented in June 2021 (Bu, 2021).

Progress has been reported on commercial trials in Vietnam for two vaccines developed by research scientists with USDA, Agricultural Research Service (ARS). One vaccine (distributed by the National Veterinary Joint Stock Company (NAVETCO) in Vietnam completed a safety assessment in April 2022 (USDA, Agricultural Research Service, 2022) and was approved for a farm trial of 600,000 doses in July 2022 (Vu & Geddie, 2022). Trials were suspended after some inoculated swine died; trials later restarted under the supervision of Vietnam's Department of Animal Health (Reus, 2023; Reuters, 2022).

A second vaccine was approved in March 2022 for limited release by the AVAC Vietnam Company in Vietnam following successful farm trials (Vietnam News Agency, 2023; Vietnam News Agency, 2022). An initial set of four batches satisfied quality requirements in early January 2023 (Reus, 2023; Vietnam News Agency, 2023; Reuters, 2022), and Vietnam's Ministry of Agriculture and Rural Development was monitoring the effectiveness of 600,000 doses of vaccine administered before large-scale release (Reus, 2023; Vietnam News Agency, 2023). The AVAC Vietnam Company made arrangements to market the ASF vaccine in the Philippines and Indonesia (Cahiles-Magkilat, 2022).

MARA (2018) announced that it had detected cases of illegal transport of animals, fraudulent health certificates, and lax ASF monitoring by local officials. The China State Council (2019) issued a wide-ranging strategy for controlling ASF that included redesigning farms to minimize infections from vehicles, people, feed, and animals entering the farm; investments in equipment and facilities for disinfection of farms and transportation equipment; banning restaurant waste from use as swine feed; strict use of ear tags on swine;

more extensive record keeping to improve traceability; establishing strict animal sanitation and inspection procedures; strict supervision of slaughter facilities; and improvements in local veterinary service systems.

Authorities banned the transportation of swine from infected areas after the first outbreaks in 2018, which meant that some regions had surplus hogs while others had shortages (Delgado et al., 2021). Rules on transportation for breeding swine and piglets were loosened in December 2018 to address shortages in some regions that were evident in the wide geographic price spreads reported by Delgado et al. (2021). Seven months later, the China State Council (2019) introduced a regionalization program to segregate China's hog market into several closed regions as a disease control strategy. The program began with a pilot program for a six-province region in southern China that prohibited shipping hogs from outside the region, allowing only breeding animals and piglets to be transported into the region. The program required tightly controlled "point-to-point" transportation from designated farms/districts to slaughterhouses within the region. After 2020, the reduced movement of vehicles and people during COVID-19 outbreaks and lockdowns might have affected the spread of ASF diseases. In 2023, some observers attributed a surge in ASF cases to the lifting of COVID-19 lockdowns and increased travel during winter holidays (Zeng, 2023).

Several veterinary research institutes and companies in China have been developing ASF vaccines, but none had successfully completed the clinical trials for commercialization as of early 2023 (see box, "ASF Vaccine Still in Development"). Huang et al. (2021) attributed the lack of a commercial ASF vaccine in China to the complexity of the virus, China's small number of labs with the security level needed to handle the virus, and the necessity of using pigs rather than mice for vaccine experiments. During 2020, illegal Chinese vaccines were blamed for the spread of virus strains that lacked genes deleted to create the Harbin Veterinary Research Institute's vaccine (Ito et al., 2022; Ma, 2021; Patton, 2021). The Chinese Government subsequently strengthened restrictions on the spread of illegal vaccines (Ma, 2021; Ito et al., 2022).

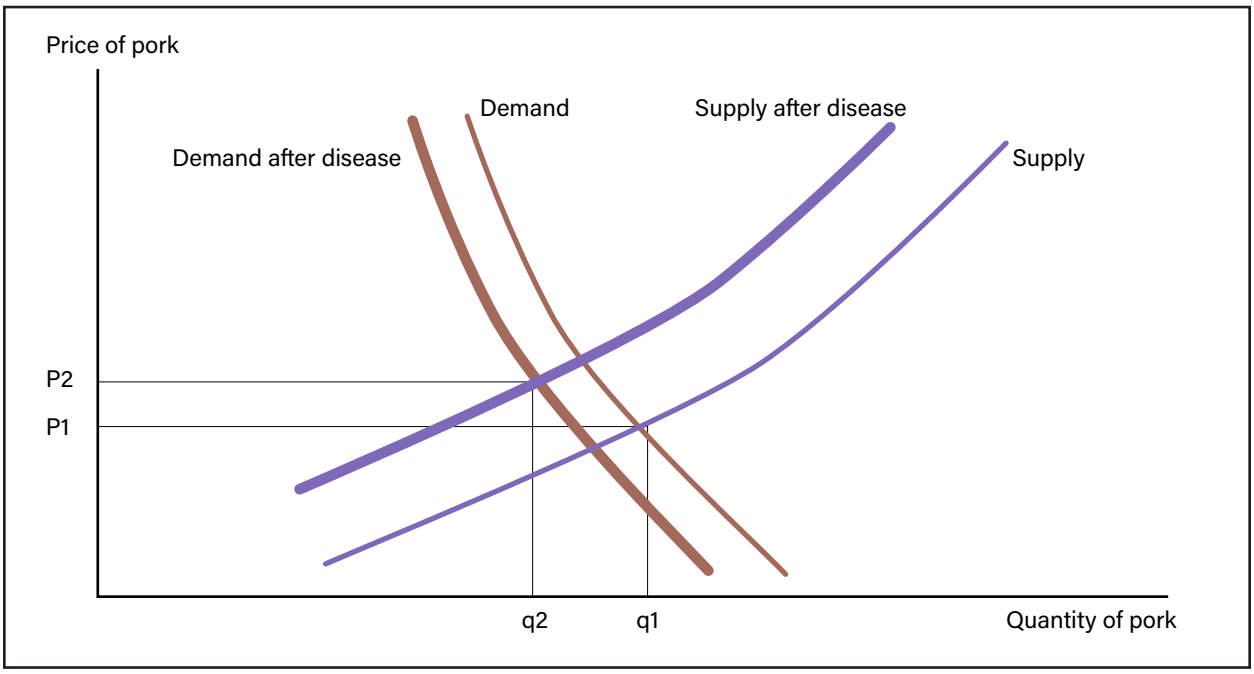
Impacts on China's Pork Market

A theoretical supply and demand diagram in figure 4 illustrates the impact of ASF on the pork market. The loss of pigs to disease reduces the supply of pork at the equilibrium price (labeled P1 in figure 4) that prevailed before the outbreak, represented by a leftward shift of the pork supply curve in figure 4. The demand may also shift leftward due to export bans and/or consumer concerns. While China is not a major pork exporter, exporting countries infected with ASF (like Germany, which had ASF outbreaks beginning in 2020) could experience reduced export demand for pork due to bans imposed by trading partners to prevent the spread of the disease. While ASF does not infect humans, many Chinese consumers reduced their pork consumption soon after ASF appeared in the country, despite a publicity campaign by Chinese authorities to assure consumers that the disease was not harmful to humans.

In figure 4, the original equilibrium quantity of pork (labeled q1) declines to a lower amount (labeled q2). A pork shortage causes prices to rise, inducing consumers to cut back their pork consumption. Higher prices may also bring additional pork supply via imports, feeding pigs to larger weights, or other strategies that are only economically viable when pork prices are high. A leftward shift in demand due to consumers' concerns about the disease (surveys found many Chinese consumers believed they could become sick from eating diseased pork) could further reduce the pork quantity, while easing upward pressure on prices. Pork supply and demand are equalized at a higher price, P2, and a lower quantity, q2. The magnitude of the price increase and quantity decrease depends on the elasticities of demand and supply.

The supply and consumption of pork both decreased substantially, but pork prices more than doubled after ASF led to reduced pork supplies in China. Pork imports surged but replaced only about one-fifth of the reduced supply. China's consumption of substitute animal proteins increased as pork prices soared.

Figure 4
Supply and demand after China's African swine fever (ASF) event



Note: This is a theoretical supply and demand diagram used for illustrating the impact of ASF on the pork market. P1 and q1 represent the price and quantity of pork produced and consumed before the disease outbreak. P2 and q2 represent the price and quantity of pork after the disease outbreak.

Source: USDA, Economic Research Service, plotted by authors.

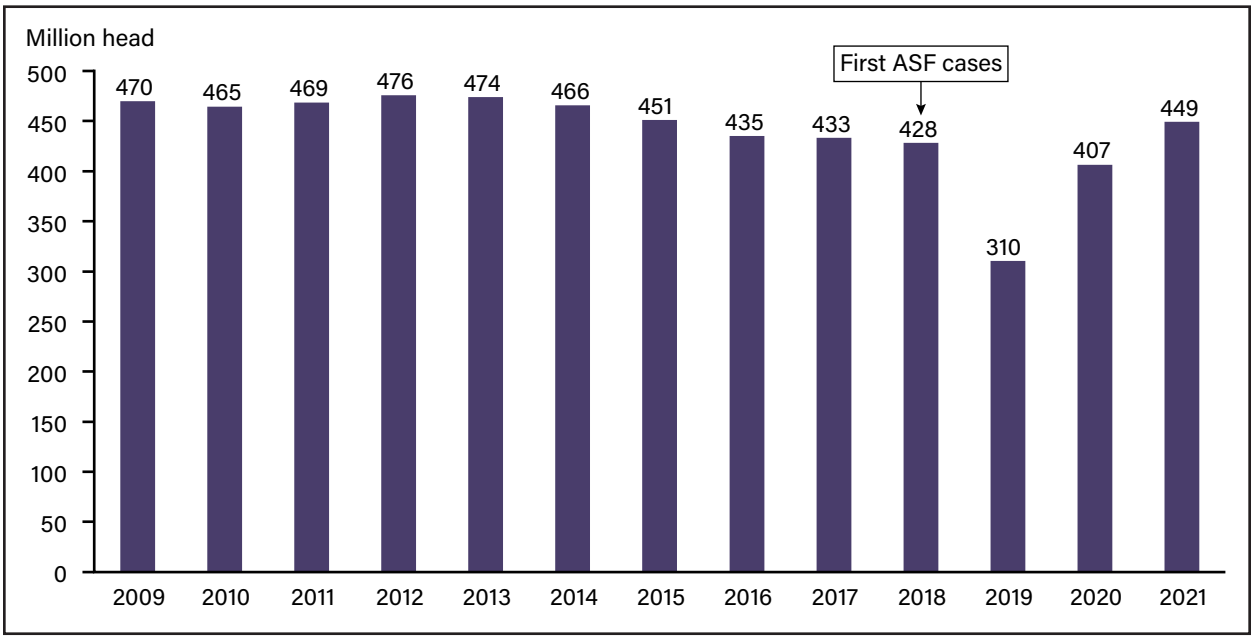
Swine Inventory Decline and Recovery

The ASF outbreak's impact on China's pork supplies was much larger than indicated by the number of cases officially reported. The Ministry of Agriculture and Rural Affairs' chief veterinarian reported that 1.1 million swine were culled during 2018–19 (China News Net, 2019), and WOAH reported 750,000 swine were culled. Data from China's National Bureau of Statistics (NBS) show that China's swine inventory (the number of swine on farms) declined by 118 million head (nearly 28 percent), from 428 million to 310 million between 2018 and 2019 (figure 5). This reduction was the largest ever decline in China's swine herd.[6] According to NBS data, the swine inventory then rebounded by 97 million to reach 407 million at the end of 2020, nearly equal to the pre-ASF number. The herd grew further to 449 million by the end of 2021—larger than the pre-ASF herd.

Videos circulating online during 2018–19 showed hundreds of pigs being buried alive and villages with dead animals piled on roadsides. News media reported that many farmers slaughtered entire herds as a preemptive measure when the farmers learned that nearby farms had been infected. Concerned that animals would be refused by slaughterhouses if their farm was infected and worried that no Government compensation would be given for culling their animals, many farmers sent their animals to slaughter before they reached market weight.

[6] The largest previous declines in China's swine inventory were statistical revisions of 15 million head following the censuses in 2016 and 2006, and 78 million head in 1996.

Figure 5
China swine inventory declined sharply in 2019



ASF = African swine fever.

Source: USDA, Economic Research Service based on data from China's National Bureau of Statistics.

A MARA (2019b) investigation of seven provinces reported widely varying reductions in numbers of sows and fattening hogs, including some breeding farms that had reduced numbers by 90 percent. The report noted that immature pigs weighing 80–90 kilograms had often been slaughtered (typical slaughter weights are 100–120 kilograms). Many farms apparently quit raising swine entirely. While the number of swine farms in China had already been falling due to the exit of small-scale farms and enforcement of environmental regulations, the decline accelerated as ASF spread through the country.

Data compiled from editions of *China Animal Husbandry and Veterinary Yearbooks* (published by China's Ministry of Agriculture and Rural Affairs) show the number of swine producers had been declining at an accelerating rate before 2018, but the loss of small farms was even faster during the first 2 years of ASF outbreaks (table 2). The number of farms raising fewer than 500 swine fell by more than 2.5 million annually during 2013 and 2014, a net exit rate that accelerated to 4.8 million farms in 2017. The loss of small swine farms accelerated to 6 million in 2018 and more than 8.7 million in 2019. The pace of growth in large-scale swine farms also slowed after ASF arrived in China, showing that the loss of small farms was not just an acceleration of the farm consolidation trend. From 2012 to 2017, the number of large farms that sold more than 50,000 head had grown annually—peaking with 96 such mega-farms added in 2017—a reflection of rapid consolidation in the industry. However, the increase slowed to 36 mega-farms in 2018 and declined by 70 in 2019 as sales plummeted and fewer farms reached the 50,000-head threshold.

Table 2
Change in number of Chinese swine farms, by size category, 2012–20

	Farm size: number of swine sold/slaughtered per year			
	<500	500–4,999	5,000–49,999	50,000 or more
Year	Change in number of farms			
2012–13	-2,593,194	10,225	282	15
2013–14	-2,578,453	975	167	24
2014–15	-2,976,843	-2,701	-23	35
2015–16	-3,941,565	-7,689	-202	50
2016–17	-4,821,698	-40,893	-186	96
2017–18*	-6,158,363	-27,680	-665	36
2018–19*	-8,788,601	-31,671	-855	-70
2019–20	-1,968,891	6,609	1,134	181

*Peak outbreaks of African swine fever were reported in China during 2018–19

Source: USDA, Economic Research Service calculations using data from China's Ministry of Agriculture and Rural Affairs, *China Animal Husbandry and Veterinary Yearbooks.*

Many pork market analysts expected a lengthy recovery based on the 17–18-month biological lag inherent in swine reproduction and growth (table 3). In November 2019, the Ministry of Agriculture and Rural Affairs' chief veterinarian cited the biological lag when he announced a goal of restoring swine inventory to 80 percent of normal by the end of 2020. After bringing the virus under control, the inventory of productive sows needed to be replenished. After sows produced new litters, the piglets then had to be raised to slaughter weight (typically 100–120 kilograms) before pork supplies could be restored. The ministry's 3-year action plan (issued in December 2019) called for restoring basic swine production capacity by the end of 2020 and normal production by 2021. The inventory of swine returned to near its pre-ASF level by the end of the first quarter 2021.

Table 3
Time needed to produce finished hogs from new sows

Birth to breeding age for new sows	7–8 months
Gestation period	4 months (114 days)
Birth to slaughter weight for commercial hog	6 months
Total time	**17–18 months**

Source: USDA, Economic Research Service based on comments by the chief veterinarian of China's Ministry of Agriculture and Rural Affairs at a November 2019 press conference.

At a January 2020 press conference, Ministry of Agriculture and Rural Affairs officials announced that the number of sows had begun to recover in October 2019 and that the national inventory of swine had begun to rebound in November 2019 (MARA, 2020a). Officials cited a broad set of policy measures taken to expedite the recovery of the swine sector (see box, "Policy Support for China's Swine Recovery").[7] Hog-producing companies benefited from credit policies, equipment purchase subsidies, and the easing of land and environmental approvals. Publicly listed companies received infusions of capital from rapid increases in their share prices as investors anticipated profitability from soaring hog prices. Companies aggressively expanded existing facilities and constructed new ones.

[7] The strong policy commitment also created incentives to exaggerate hog production data to meet targets given to provincial and local authorities and to demonstrate results from subsidy expenditures.

NBS data showed that the swine inventory grew by 97 million between December 2019 and December 2020. The data on swine farm numbers shown in table 2 indicate increases in the number of farms raising 500 head or more during 2020, consistent with reports of new farm construction contributing to the recovery. The increase included a gain of 196 farms raising 50,000 head during 2020. The number of small farms raising less than 500 head declined again in 2020 but at a slower pace of less than 2 million that year, the smallest decline since 2012.

Producers adopted strategies that accelerated the recovery of pork output. Producers shortened the breeding cycle by directly using female market hogs meant for commercial fattening as breeding sows. Industry reports noted that these sows accelerated recovery of production but had lower productivity and were prone to introducing the ASF virus into farrowing facilities. Many producers raised hogs to larger-than-normal weights, including a practice of so-called "second fattening" of hogs that were already at customary market weights.[8]

Decline and Recovery Cycle of 30 Months

Quarterly swine inventories derived from NBS reports show that the decline and recovery of swine numbers occurred over approximately 30 months (figure 6). The inventory was relatively stable during 2018 Q4 (the first 3 months after the first reported outbreaks). Nearly all the contraction in the herd occurred during the first three quarters (9 months) of 2019. The swine inventory reached a low point of 307 million at the end of the third quarter of 2019, about a year after the first outbreaks. The swine inventory recovered marginally to 310 million during the fourth quarter of 2019.

Most of the swine recovery occurred during 2020, as the inventory grew to 407 million by 2020 Q4. By the end of 2021 Q1, the swine inventory had reached 416 million, within 3 percent of the inventory reported at the beginning of the ASF outbreak. Thus, the official data indicate the swine herd had rebounded close to its pre-ASF size six quarters (18 months) after reaching its low point and 10 quarters (30 months) after the initial ASF disease reports. The data show that the swine inventory continued growing to 449 million by the end of 2021. (The inventory declined again during the first half of 2022 when a sharp decline in prices and renewed ASF outbreaks prompted increased slaughter.)

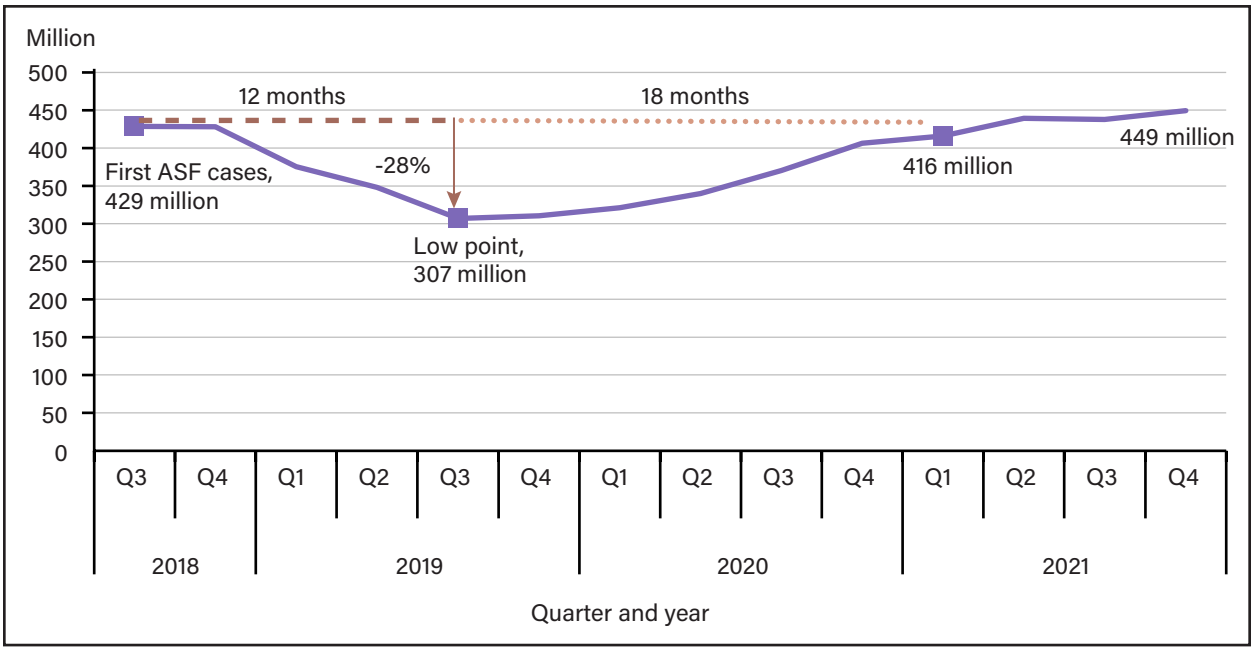
China's Ministry of Agriculture and Rural Affairs has a parallel monthly reporting system for swine numbers that indicates a larger decline in swine inventories than indicated by the NBS data and a corresponding larger recovery.[9] USDA, ERS calculations (using Ministry of Agriculture and Rural Affairs' reported monthly changes in inventory) showed a 41-percent decline in swine inventory from 2018 Q3 to 2019 Q3,[10] exceeding the 28-percent decline reported by NBS over the same period. The timing of the decline and recovery shown by the Ministry of Agriculture and Rural Affairs data were broadly similar to those shown by NBS, except that the Ministry of Agriculture and Rural Affairs data showed an earlier 5-percent decline in 2018 Q4 (one quarter earlier than NBS). The Ministry of Agriculture and Rural Affairs reported a strong recovery of swine inventory during 2021, with monthly growth ranging from 2.8 percent to 4.8 percent from February to December 2021.

[8] The Chinese term second fattening (二次育肥) refers to producers buying 100–120 kilogram "standard hogs" from the market, fattening the hogs to 150 kilograms or more, and then reselling these hogs for slaughter.

[9] Ministry of Agriculture and Rural Affairs estimates are based on data from 400 fixed locations (a mix of villages and large-scale farms), and NBS data are based on a sample survey, but neither statistical system has detailed documentation available to the public. NBS data are considered official. A Ministry of Agriculture and Rural Affairs report issued in March 2018 revealed that the sample had been adjusted to reflect the changed structure due to the closure of farms for compliance with environmental regulations and the expansion of larger-scale farms. MARA (2020c) acknowledged problems in livestock data reporting and ordered local officials to conduct spot checks of large farms and establish a record system for small farms.

[10] USDA, ERS authors multiplied monthly changes starting from 2018 (quarter 3) to estimate cumulative changes in swine inventory after the initial outbreaks.

Figure 6
Decline and recovery of China's swine inventory, 2018–21



ASF = African Swine Fever. Q1, Q2, Q3, and Q4 = quarter 1, quarter 2, quarter 3, and quarter 4.

Source: Compiled by USDA, Economic Research Service from China's National Bureau of Statistics quarterly reports.

Policy Support for China's Swine Recovery

In August 2019, a vice premier of China held a national video conference for local officials emphasizing the political importance of adopting policies to accelerate the recovery of pork supplies (China Government Net, 2019). In September 2019, China's State Council issued an "Opinion on Stabilizing Hog Production and Promoting a Transformational Upgrade" (国务院办公厅关于稳定生猪生产促进转型升级的意见). In December 2019, China's Ministry of Agriculture and Rural Affairs issued a 3-year action plan to restore normal swine production by 2021. Pork production policies were also folded into rural poverty eradication and rural revitalization initiatives underway at the time. In a January 2020 news conference, officials cited policies the vice premier credited for hastening the sector's recovery (MARA, 2020a).

Central Government authorities budgeted:

- 300 million yuan to aid the construction of large-scale hog breeding and finishing farms.
- 700 million yuan to increase aid for major hog-producing counties.
- 220 million yuan to compensate farmers for swine culled to control ASF outbreaks.
- 400 million yuan to subsidize loans for the purchase of 22 kinds of hog-farming equipment, such as automated feeding equipment, environmental control facilities, and disease prevention and waste treatment.
- 180 million yuan in cash subsidies for the purchase of equipment by 72,000 livestock farmers.

Officials waived certain regulations and fees to boost pork supplies:

- Environmental assessments of hog farms were eased.
- Local officials were ordered to reevaluate environmental-related bans on livestock farms in certain districts and to simplify and ease approvals of agricultural and forest land for use as pig farms.
- Highway tolls were waived temporarily for trucks transporting piglets and chilled pork.

Companies and banks were encouraged to take measures to increase pork production capacity:

- Banks and financial organizations were prompted to expand loans to hog farms by 19.8 billion yuan. Pilot programs to issue mortgage loans secured by live swine were launched in some provinces.
- Subsidized insurance covered 18.85 million sows and 300 million finishing hogs.
- Agricultural officials coordinated agreements between leading hog production companies and 20 poverty-alleviation areas to expand hog production by 22 million head.

Additional policies cited in the 2021 edition of the Ministry of Agriculture and Rural Affairs' *China Animal Husbandry and Veterinary Yearbook* included 2-percentage-point interest rate subsidies for working capital loans that could be supplemented by local subsidies; subsidies for improved-breed semen and artificial insemination of up to 40 yuan per sow per year; and subsidized insurance for 31.2 million sows and 382 million finishing hogs with increased indemnity payments.

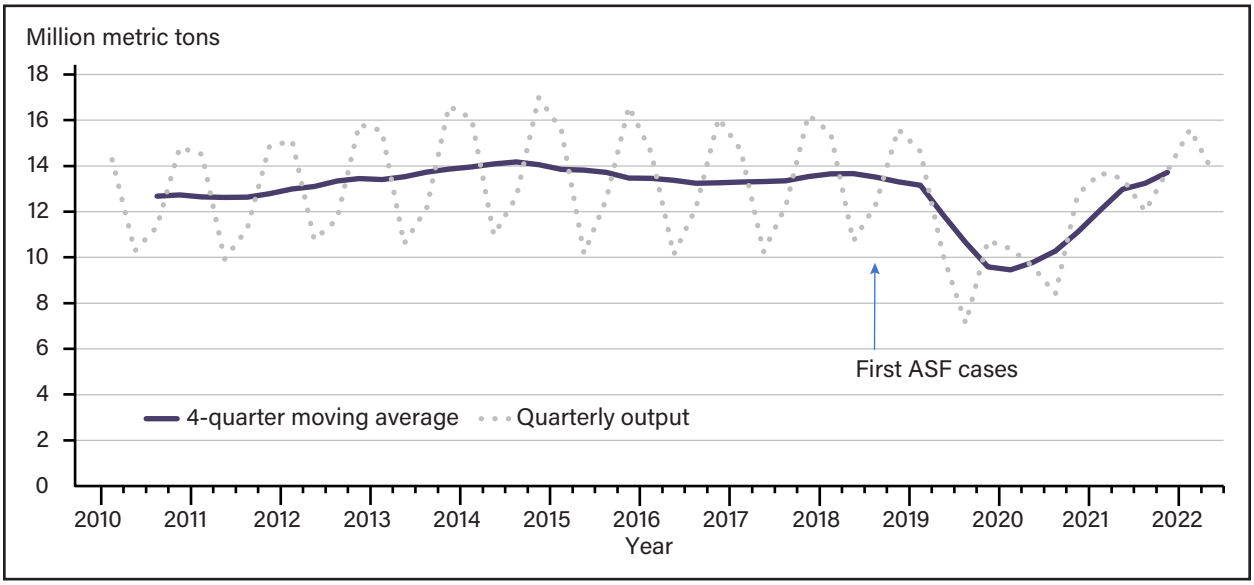
China Lost an Estimated 27.9 Million Tons of Pork Output

The decline in swine inventories restricted the supply of pork since fewer hogs were available for slaughter.[11] Annual NBS data reported pork output in 2019 was down 21 percent from 2018, and 2020 output was down 24 percent from 2018. Pork output in 2021 rebounded to near the 2018 level. Investigation of quarterly pork output data indicates that output reductions did not occur until the second half of 2019, so the decrease in annual production understates the impact on supply.

The strong seasonality of pork output makes it difficult to measure quarterly changes. China's pork output tends to follow annual consumption cycles. Pork production is highest in the first and fourth quarters of each year, reflecting the concentration of holidays and peak consumption during September–February. China also has a tradition of slaughtering pigs at the end of the calendar year to prepare cured meat products. Production is typically low during the winter months following the holiday season, and production is low during the summer months due to hot weather and school vacations.

A four-quarter moving average smoothed seasonal variation in quarterly pork output and showed more clearly the unusual decline in pork output during 2019 and its recovery in 2021 (figure 7). During the years before the ASF epidemic (2010–17), the moving average had a mean of 13.4 million metric tons of pork per quarter, and the quarterly output fluctuated within a range of 9.9 million metric tons to 16.6 million metric tons. There was no sustained rising or falling trend in pork output over time; rather, the highest values were reported during 2014.[12] The lowest moving average value was 9.45 million metric tons in 2020, about 29 percent below the 2010–17 mean (consistent with the 28-percent decline in swine inventory). The moving average began rising in 2020 and recovered to 13.7 million metric tons in 2021.

Figure 7
China's quarterly pork output, 2010–22



ASF = African swine fever.

Note: Moving average = .25 * (Qt-2 + Qt-1 + Qt + Qt+1).

Source: USDA, Economic Research Service compiled from China's National Bureau of Statistics quarterly macroeconomic data reports.

[11] During 2020–21, there were many reports of farmers raising hogs to weights of 150 kilograms—about 30–40 percent more than customary slaughter weights—to take advantage of high hog prices. However, NBS's data indicate a very small change in the ratio of pork per hog slaughtered from 77.9 kilograms to 78.2 kilograms between 2018 and 2019.

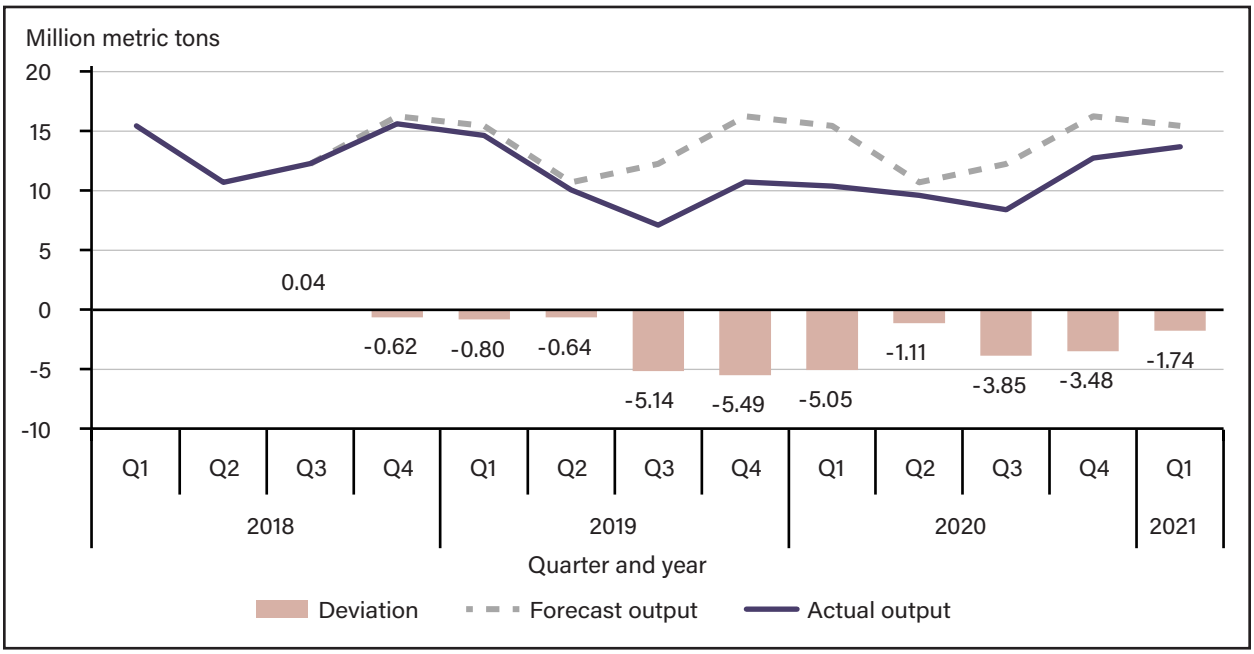
[12] Seasonal peaks are during the holiday months of the fall and winter, and low production is during the spring and summer months.

USDA, ERS researchers calculated the impact of ASF on China's quarterly pork output by forecasting values based on historical patterns and fluctuations, then calculating the deviation of actual output from the forecasted output for the time period after the first ASF outbreaks (see box, "Measuring Post-ASF Output Shortfall").[13] The authors estimated a time series model to identify the trend, seasonality, and temporal dynamics of pork output during 2010 Q1 to 2018 Q2 before the disease affected the swine herd. Then forecasts from the model were used as a counterfactual estimate of what "normal" output would have been in the absence of ASF for 2018 Q3 and the quarters that followed. The deviation of actual output from the forecasted output was used to estimate the impact of ASF herd losses on quarterly output beginning in 2018 Q3.

Figure 8 shows the predicted quarterly pork supply, actual pork supply, and the deviation of actual supply from the predicted supply from 2018 Q3 to 2021 Q1. The first negative deviations are observed in 2018 Q4 through 2019 Q2, ranging from 620,000 metric tons to 800,000 metric tons. The largest deviations are observed in 2019 Q3 (5.14 million metric tons), 2019 Q4 (5.49 million metric tons), and 2020 Q1 (5.05 million metric tons). The deviations taper off in 2020 Q3 (3.85 million metric tons), 2020 Q4 (3.48 million metric tons), and 2021 Q1 (1.74 million metric tons). The 2020 Q2 deviation is small (1.11 million metric tons), which could reflect a delay of slaughter due to the closure of many slaughter facilities during the peak of the COVID-19 pandemic in 2020 Q1, or the deviation may reflect data problems.

The cumulative deviations over the 10 quarters (30 months) from 2018 Q4 to 2021 Q1 totaled 27.9 million metric tons, representing an estimate of the total pork output lost due to ASF herd losses. The cumulative forecast output over that period was 153 million metric tons. Thus, the estimates suggest that the losses in pork output were equivalent to 18 percent of "normal" output that may have occurred without the impacts of ASF outbreaks.

Figure 8
China's pork output, forecast and actual, 2018–21



Q1, Q2, Q3, and Q4 = quarter 1, quarter 2, quarter 3, and quarter 4.

Note: Actual quarterly output is from China's National Bureau of Statistics; forecast output is from the Auto-Regressive Integrated Moving Average (ARIMA) model. The deviation is the difference between the actual and forecast output.

Source: USDA, Economic Research Service analysis of China's National Bureau of Statistics data.

[13] This analysis uses official Chinese data for all items. USDA Production, Supply and Distribution (PSD) estimates of China's pork output are lower than official data beginning in 2020.

Measuring Decline in Chinese Pork Output

The average quarterly pork output for 2010–17 was 13.4 million metric tons. Quarterly averages were relatively stable from year to year: quarter 1 (Q1) 15.1 million tons; Q2 10.4 million tons; Q3 12 million tons; and Q4 16 million tons. Preliminary analysis showed that the pork output data in pre-African swine fever (ASF) years 2010–17 was nonstationary, with strong seasonality and no clear trend evident.

USDA, Economic Research Service researchers analyzed the data using a seasonal Auto-Regressive Integrated Moving Average model, ARIMA(p, d, q)(P, D, Q)$_s$. In this model, p is nonseasonal autoregressive (AR) order, d is nonseasonal differencing, q is nonseasonal moving average (MA) order, P is seasonal AR order, D is seasonal differencing, Q is seasonal MA order, and s is number of observations per year. The model estimation period is from Q1 2010 to Q2 2018, with 34 observations.

The model that fit the data most closely was an ARIMA(0,0,1)(0,1,0)$_4$ model with no constant and no trend, with seasonal first differencing, and with a moving average component of order 1. This specification generated the lowest Akaike Information Criterion value (AIC). The residuals showed no autocorrelation.

The MA(1) component had a coefficient of 0.9206, with a standard error of 0.1048. The estimate suggests that an unexpected change in one quarter's output had an impact in the same direction on the pork output in the following quarter after seasonality is taken into account.

Pork Reserve Sales Were Comprised of Imported Pork

Changes in pork inventories are another source of supply. Inventories are held in frozen form by meat companies. Some inventories are held on behalf of Chinese Central, Provincial, and Municipal Government reserve systems (with a subsidy), but meat packers also hold private inventories. Sales of Central Government reserves are publicly announced, but the volume of reserves is not revealed to the public.

News reports indicated that meat companies accumulated inventories of pork during the early months of 2019 when many farmers were panic slaughtering herds. Data presented by an industry analyst indicated that frozen pork inventories held by meat companies more than doubled between February and April 2019, then returned to near their February level by October 2019 (Bohmbach, 2019). The amount of these inventories was not publicly reported.

Releases of Chinese Government pork reserves began in September 2019. USDA, ERS researchers compiled documents from China's National Commodity Reserve Center announcements of pork reserve sales indicating that 1 million tons of pork were released from September 2019 through March 2021. However, the documents stated that nearly all the reserve pork released during these months was imported. Thus, the release of reserves appears to have been a conduit for releasing imported pork into the market during these years. The prominence of imports in reserve releases implies that China's pork stockpile was not large enough to significantly fill the deficit.

Pork Imports Replaced About One-Fifth of the Loss in Production

An increase in net imports of pork partially replaced the loss of domestic production in China's pork supply. Analysis of China's customs data shows that pork imports rose from under 500,000 metric tons during the second and third quarters of 2018 to 730,000 metric tons in 2019 Q2 (figure 9).[14] Then net imports reached 1.18 million metric tons during Q1 2020, more than double the imports' year-earlier amount. Net imports

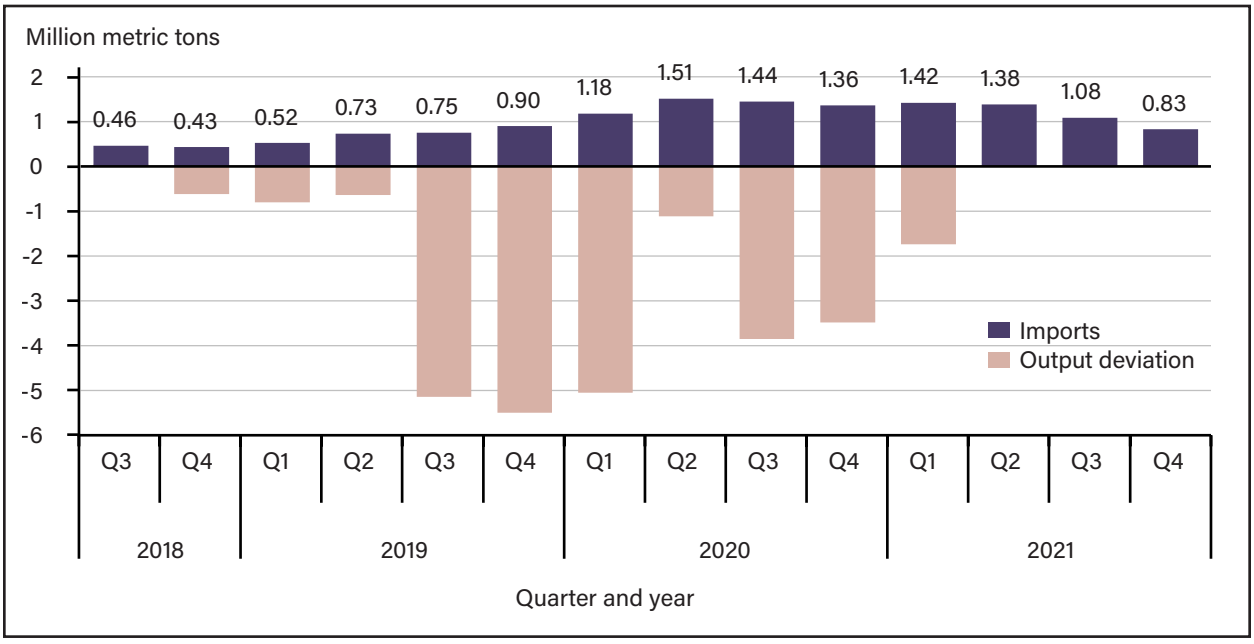
[14] In contrast to the pork output data, analysis of pork import data did not reveal any seasonal patterns.

peaked at 1.51 million metric tons in Q2 2020—by far the largest amount of pork China had ever imported. Imports remained at a high level through Q2 2021, when imports were still 1.38 million metric tons. Imports began to decline during 2021, reaching 830,000 metric tons in 2021 Q4. USDA, ERS calculations indicate that imports comprised 3–5 percent of China's pork supply during 2018 and rose to a peak of about 14 percent during 2020 Q2 and Q3. The import share of supply was 9–10 percent from 2020 Q4 to 2021 Q2, then fell to 5.7 percent in 2021 Q4.

The cumulative volume of imports from 2018 Q4 to 2021 Q1 was 10.25 million metric tons, a volume that is likely much higher than would have occurred without ASF. If ASF had not occurred and imports had continued at their pre-ASF volume of 500,000 metric tons per quarter, then 5 million metric tons would have been imported during the 10 quarters from 2018 Q4 to 2021 Q1. Based on this assumption, the actual imports of 10.25 million metric tons over those 10 quarters exceeded the 5-million-ton "normal" volume by 5.25 million metric tons.

Thus, the cumulative excess imports of 5.25 million metric tons replaced nearly one-fifth of the 27.9 million tons of reduced pork output. After accounting for the increase in imports, the net decline in pork supplies over 2018 Q4 – 2021 Q1 was -22.65 million metric tons (-27.9 million metric tons + 5.25 million metric tons).

Figure 9
China's pork imports and pork production shortfall



Q1, Q2, Q3, and Q4 = quarters 1, 2, 3, and 4.

Note: Pork imports include harmonized system categories defined by the World Trade Organization as constituting "pork and pork products:" 0203, 020641, 020649, 0210, 1602. The production shortfall was shown in figure 8.

Source: USDA, Economic Research Service analysis of China customs data accessed through the Trade Data Monitor.

Pork Consumption Fell; Consumption of Poultry, Eggs, Fish, and Shellfish Increased

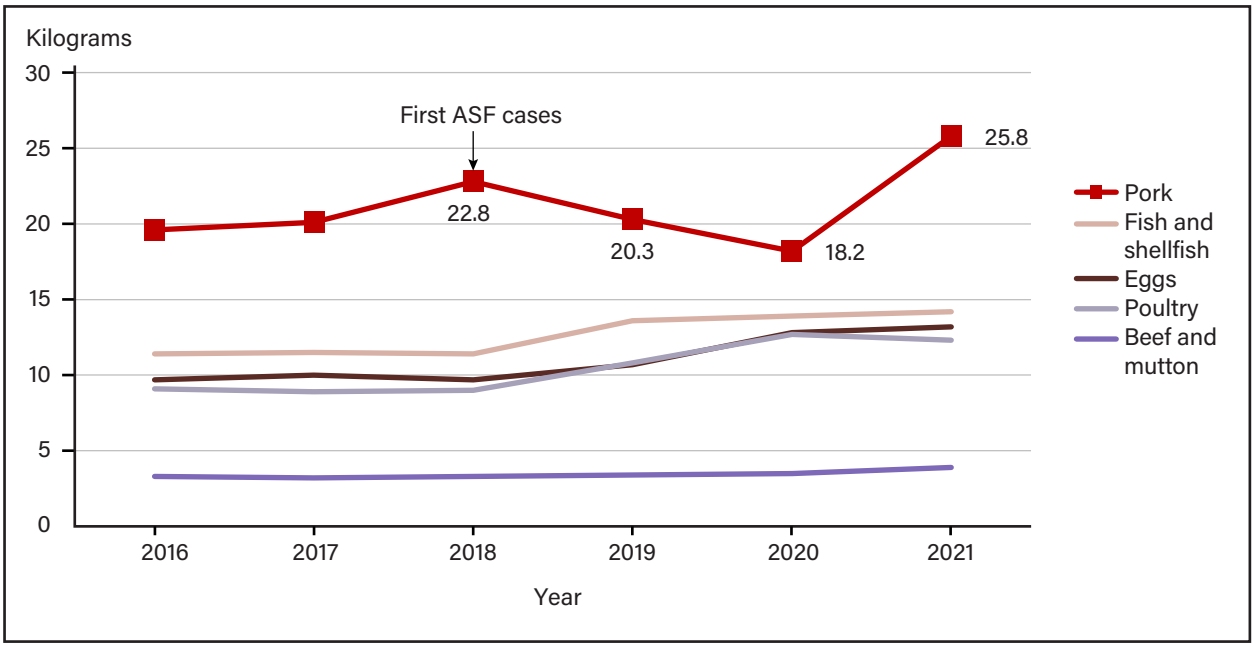
Pork consumption was rarely discussed by Chinese news media during the ASF-induced pork shortage, and only a few studies analyzed the effect of ASF on pork consumption. Agricultural officials issued statements in news media during 2018–19 assuring consumers that the disease could not be spread to humans by consuming pork (e.g., Xinhua News Service, 2019). Nevertheless, a survey of residents in the region where the first outbreak occurred found that consumers had reduced their pork consumption because most thought the virus could affect humans (Zhu et al., 2019). Four months after the first outbreaks, a report observed that pork prices were depressed due to worries about catching the virus from pork (Xie & Li, 2018). A later survey of consumers in 20 provinces by China Agricultural University found that only 42.5 percent of respondents knew that ASF was not transmissible to humans, and only 60 percent thought that pork purchased through legal distribution channels was safe (Zeng et al., 2020).

Hao et al. (2022) found that per capita pork consumption declined and poultry consumption increased after the ASF outbreaks, but overall meat consumption fell significantly. A study of household survey data gathered by the National Bureau of Statistics Sichuan Survey Team in China's largest pork-consuming region estimated that Sichuan Province's monthly per capita pork consumption decreased by 0.64 kilograms (kg), with larger impacts on low-income and rural consumers (Zhang et al., 2020). The Sichuan study also observed that rising pork prices contributed to an increase in food expenditure, despite the reduction in quantity consumed.

Data from the NBS household survey illustrate the changes in animal protein consumption. This survey understates consumption by excluding consumption away from home in restaurants and cafeterias, but the patterns reported are broadly consistent with changes in supply calculated above. The survey reported that average per capita purchases of pork decreased from 22.8 kg in 2018 to 18.2 kg in 2020, a net decline of 4.6 kg (20 percent) over 2 years (figure 10). The data show that pork consumption then increased by 7.6 kg in 2021 to reach 25.8 kg, a record level. The household data also indicate increases in the consumption of poultry, eggs, fish, and shellfish during 2018–20 (table 4).[15]

[15] The survey data show increases in the consumption of nearly all foods in 2021, indicating either a flaw in the survey or possibly a shift in consumption from away-from-home (not included in the survey) to at-home consumption during the COVID-19 pandemic.

Figure 10
Chinese household per-capita purchases of pork and other animal proteins, 2016–21



ASF = African swine fever.

Note: Per capita consumption is reported by the national household income and expenditure survey.

Source: USDA, Economic Research Service based on data from China National Bureau of Statistics, *China Statistical Yearbook*.

Table 4
Change in per capita consumption of pork and other animal protein, 2018–21

Years	Pork	Poultry	Eggs	Beef and mutton	Fish and shellfish
			Kilograms		
2018–20	-4.6	3.7	3.1	0.2	2.5
2020–21	7.6	-0.4	0.4	0.4	0.3

Source: USDA, Economic Research Service calculations using data from figure 11.

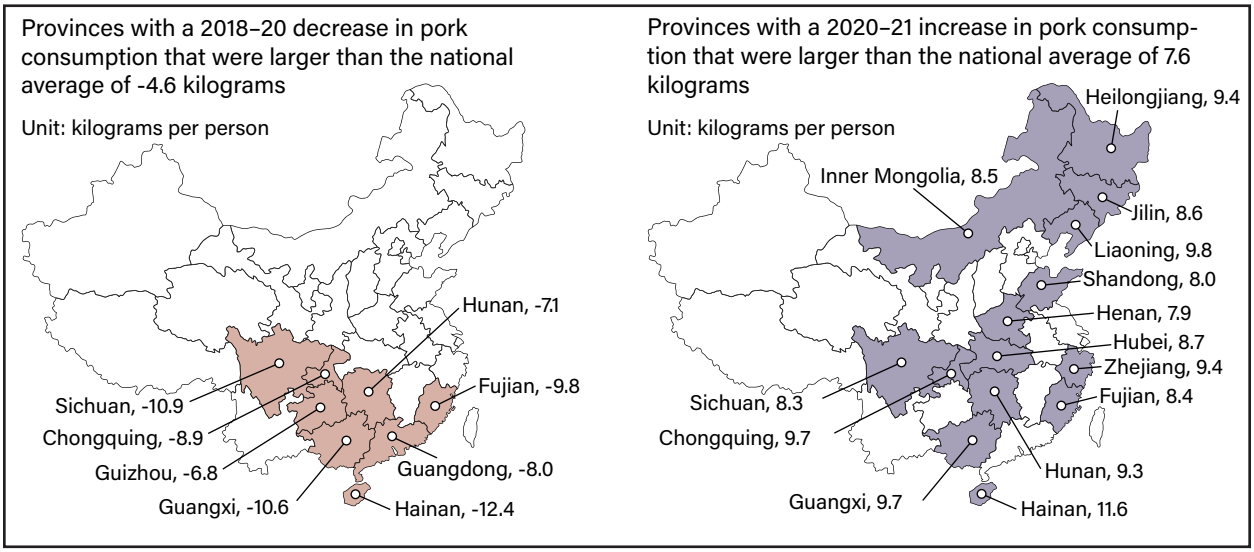
Reductions in pork consumption were larger in rural and in southern regions. The household survey data show that per capita pork consumption for rural and urban households was nearly equal in 2018, but rural consumption declined 5.7 kg during 2018–20 while urban consumption declined 3.7 kg. The rebound in rural consumption was also stronger: Rural and urban pork consumption were nearly equal again in 2021.

Thirty of China's 31 provinces reported a decline in per capita pork consumption between 2018 and 2020 (Tibet had no change). The decrease in pork consumption during 2018–20 exceeded the national average of -4.6 kg in eight provinces, all in southwestern and southern regions (figure 12). The largest declines were in Hainan (-12.4 kg), Sichuan (-10.9 kg), and Guangxi (-10.6 kg) Provinces. Other provinces with declines ranging from -9.8 to -6.8 kg were Guangdong, Fujian, Chongqing, Hunan, and Guizhou.

Between 2020 and 2021, all provinces except Tibet had increases in per capita pork consumption. Fourteen provinces had increases exceeding the national average of 7.6 kg. Hainan had the largest increase (11.6 kg), and 13 other provinces had increases ranging from 7.9 kg to 9.8 kg. Provinces with rapid increases were spread geographically across the southern, central, eastern, and northeastern regions. Several provinces that

had large pork consumption declines during 2018–20 had large increases in 2020–21 (Hainan, Sichuan, Chongqing, Guangxi, Hunan, and Fujian). Two provinces with large decreases during 2018–20 had increases below the national average during 2020–21 (Guangdong and Guizhou). Changes for all provinces are shown in appendix table 3.

Figure 11
Per capita pork consumption: Chinese provinces with the largest decreases during 2018–20 and largest increases during 2020–21



Source: USDA, Economic Research Service analysis of per capita pork consumption reported by the China National Bureau of Statistics, *China Statistical Yearbook*.

Consumer Pork Prices Rose 119 Percent

The shortfall in pork supplies resulted in a dramatic rise in China's pork prices during 2019–20, followed by a decline in prices during 2021. Monthly consumer price index (CPI) reports issued by NBS during 2019–20 showed that pork prices rose much faster than any other item. When pork prices were at their peak in January 2020, the report noted that the rise in pork prices from a year earlier accounted for more than half of that month's 5.4-percent annual growth in CPI. The large increase in the Chinese pork price implies that the leftward shift of the demand curve was relatively minor compared to the leftward shift in pork supply (see figure 4).

The changes in Chinese hog and pork prices are illustrated in figure 12. USDA, ERS analysts chose August 2018 as a base month (the month of the first outbreaks) and calculated cumulative changes in prices from the base month for each month through June 2022. Calculations were performed using monthly wholesale prices for live hogs and pork carcasses reported by China's Ministry of Agriculture and Rural Affairs and consumer pork price indexes reported by NBS in monthly CPI reports.

Prices of live hogs and pork fluctuated in parallel. Each of the three prices (for hogs, wholesale pork, and consumer pork) grew rapidly from the first outbreaks to an initial peak reached in November 2019. Then prices fluctuated at a relatively high level for 14 months from November 2019 to January 2021. Prices then fell rapidly until September 2021, when the wholesale hog and pork prices fell to the same level where they had started in August 2018. Consumer prices were still about 5 percent above their August 2018 level. Prices then began a new pattern of fluctuation during 2021–22.

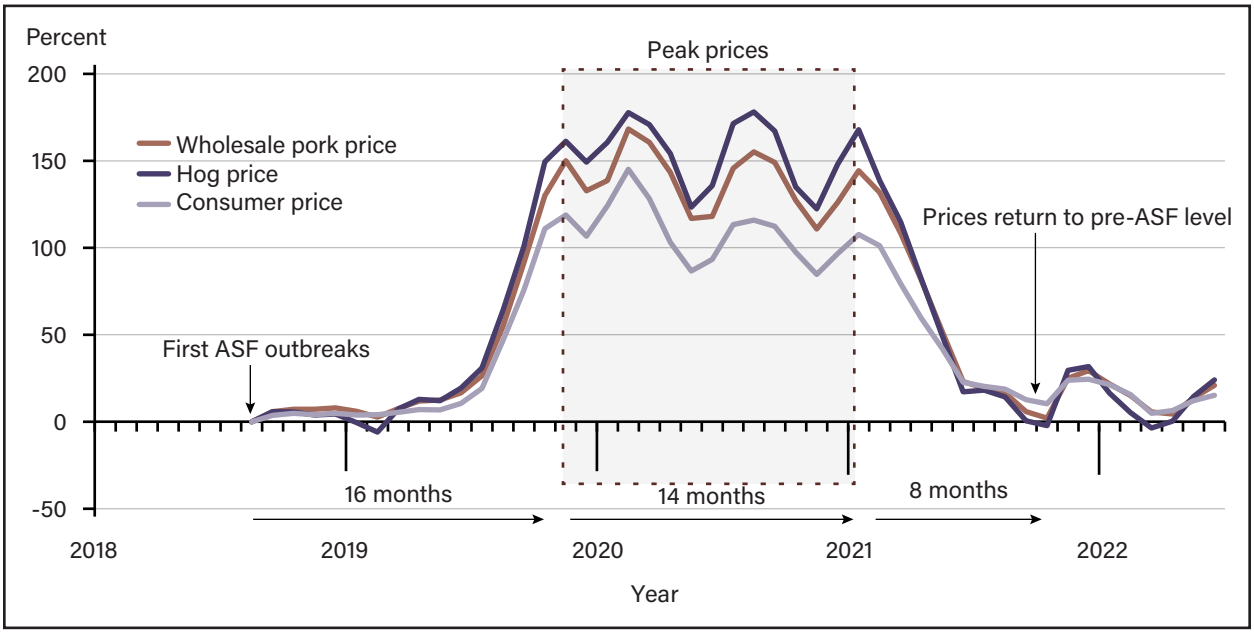
A 38-month cycle of hog and pork price growth and decline can be delineated into three phases from August 2018 to September 2021 (the month prices returned to their August 2018 level):

- Rising prices from August 2018 to November 2019 (16 months)
- Peak prices from November 2019 to January 2021 (14 months)
- Falling prices from January 2021 to September 2021 (8 months)

The Chinese hog and pork price cycle roughly corresponds to the cycles in inventory and pork output. Prices began to accelerate during March 2019 (about 7 months after the first outbreaks) and reached their peak in November 2019. The acceleration of price increases in 2019 Q3 corresponds to the minimum swine inventory and large deficits in pork output detected during that quarter. The decline in prices began in 2021 Q1, the same period when the authors detected a narrowing of the pork output deficit and return of inventory to its pre-ASF level. Prices fell during the following 9 months after inventories and output had returned to pre-ASF levels. Pork imports remained high during 2021, adding to supplies and putting downward pressure on prices.

From August 2018 to November 2019, hog prices increased by 155 percent, wholesale pork prices increased by 139 percent, and consumer pork prices increased by 119 percent (table 5). The period of peak prices with relatively minor fluctuations lasted for 14 months (November 2019–January 2021). The decline in hog and pork prices from the peak period to October 2021 was -59 percent for hog prices, -56 percent for wholesale pork prices, and -47 percent for consumer pork prices.

Figure 12
Growth in China's hog and pork prices after the first ASF outbreaks



ASF = African swine fever.

Note: Each price is indexed to August 2018. The chart shows the cumulative change in price from August 2018 to the current month. The wholesale pork price is for a carcass with internal organs, feet, and head removed. Consumer price changes were calculated from monthly consumer pork price indexes.

Source: USDA, Economic Research Service based on monthly averages from weekly livestock and feed market price reports posted online by China's Ministry of Agriculture and Rural Affairs and consumer price index reports posted online by China's National Bureau of Statistics.

Table 5
Change in China's hog and pork prices after African swine fever (ASF) outbreaks

Time period	Hog price	Wholesale price[1]	Consumer pork price[2]
		Percent	
Pre-ASF to peak price period	155	139	119
Peak price period to post-ASF	-59	-56	-47

[1] Wholesale price is for carcass after removal of internal organs, blood, feet, head, and skin.

[2] Consumer price changes are calculated from monthly consumer price index reports.

Note: Pre-ASF is August 2018. Peak price period is November 2019 to January 2021. Post-ASF is September 2021 (see figure 13). Price changes for hogs and wholesale pork were calculated from prices in Chinese yuan.

Source: USDA, Economic Research Service based on monthly averages from weekly livestock and feed market price reports issued by China's Ministry of Agriculture and Rural Affairs and the China National Bureau of Statistics.

Impacts on the Global Pork Market

Large Impacts Were Expected

Since China accounts for nearly half of global pork consumption (42 percent in 2022), its increased import demand during the ASF outbreak was expected to drive up prices in the world pork market (OECD, 2022). China had already become the world's top pork importer in 2016 and 2017 before ASF reduced Chinese pork supplies. Data from USDA's Production, Supply, and Distribution (PSD) database indicate that China accounted for 17.1 percent of the world's pork imports in 2018 (the year ASF reached the country)—a share that more than doubled after ASF reduced China's pork supplies (table 6).[16]

A year after ASF was first reported in China, Rabobank (2019a) declared that China's hog losses had "…surpassed the world's ability to make up the difference." Rabobank noted that the European Union (EU) was the leading global pork supplier and observed that the capacity of the United States and Canada to export more pork to China was constrained by China's retaliatory tariffs on U.S. pork and by China's political strains with Canada. China's pork imports boomed, despite constraints on pork exports from some European countries due to their own ASF outbreaks and China's imposition of measures to prevent transmission of COVID-19 on imported frozen foods.

Many pork market analysts expected the increase in pork shipments to China to affect markets worldwide. For example, a Rabobank (2019b) analysis warned that the diversion of pork exports to China would cause unexpected supply shortfalls in other markets and result in increased global protein prices. Industry leaders quoted by Polansek (2019) anticipated shortages of pork in the U.S. market due to the increased volume exported to China.

China Accounted for 45 Percent of World Pork Imports in 2020

USDA data indicate that China imported 1.457 million tons of pork (carcass weight equivalent) during 2018, the year of the first ASF outbreaks (table 6). China's import volume then rose to a peak of 5.28 million metric tons in 2020. China was the top pork-importing country in 2019 and remained in that position as its share of world imports climbed to 45 percent in 2020. The import quantity fell to 4.33 million metric tons in

[16] PSD data are used to summarize global pork supply and demand. The sections below analyze customs data that are available quarterly and for various categories of pork.

2021, but that was still 37 percent of all pork imports. Chinese pork imports fell to 1.8 million metric tons in 2022, dramatically lower than in 2021 but still larger than any pre-ASF total besides 2016. China's 18.8-percent share of world imports in 2021 was slightly larger than in 2017–18, and China still was the largest pork importer. Taking a broader view of world pork supplies, calculations based on USDA data confirm that China's surge of imports constituted a significant portion of the global pork trade. China's imports equaled 1.3 percent of world pork output in 2018 and rose to 5.5 percent in 2020. The ratio fell to 1.6 percent in 2022.

Table 6
China's share of world pork imports, 2010–21

Year	Share of world imports	Imported quantity[1]	Rank[2]
	Percent	1,000 metric tons	
2010	7.44	406	4
2011	11.6	710	3
2012	10.7	683	3
2013	11.8	728	3
2014	12.0	720	2
2015	14.9	955	2
2016	23.7	2,021	1
2017	17.7	1,501	1
2018	17.1	1,457	2
2019	26.3	2,451	1
2020	45.2	5,281	1
2021	37.3	4,330	1
2022[3]	18.8	1,800	1

[1] Carcass weight equivalent.

[2] China's rank as a pork importer.

[3] Forecast as of December 2022.

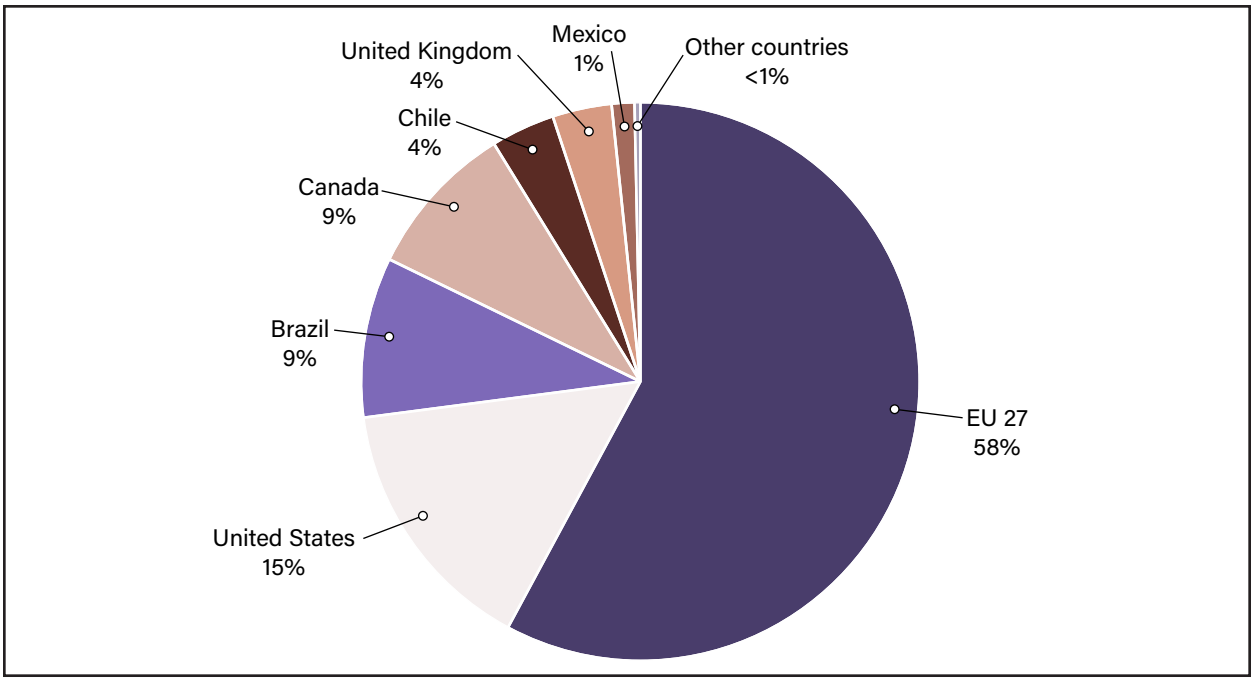
Source: USDA, Economic Research Service based on the USDA Production, Supply, and Distribution (PSD) database.

The European Union Supplied 58 Percent of China's Pork Imports in 2018–21; the U.S. Share Was 15 Percent

Producers in many countries exported a larger volume of pork to China after the ASF outbreak reduced its pork supply. The authors analyzed customs data reported by exporting countries to assess the impact on exporters. The European Union, United States, and Canada were the top exporters of pork to China before the ASF outbreak, but a total of 31 countries exported pork to China. After China's ASF outbreak, these three countries expanded their exports, and Brazil became another top exporter to China. Seven new countries (Belarus, India, Switzerland, Myanmar, Georgia, Montenegro, and Argentina) began exporting pork products to China. Portugal, a member of the EU, gained access to China's pork market in 2019.

During 2018–21, the EU, United States, Brazil, and Canada together accounted for 91 percent of pork exports to China (figure 13). The EU alone accounted for 58 percent. The top EU countries supplying pork to China included Spain, Germany, Denmark, the Netherlands, France, and Ireland. The United States accounted for 15 percent, and Brazil and Canada supplied 9 percent each. Chile (4 percent) and Mexico (1 percent) were other significant pork exporters to China. Seven new countries began exporting pork to China for the first time during 2018–21, although their share of exports to China was under 1 percent. Argentina and Switzerland accounted for nearly all the exports from new countries.

Figure 13
Share of world pork exports to China, by exporting country, 2018–21



Note: EU 27 represents 27 member states of the European Union. Shares are based on metric tons exported by each country/region.

Source: USDA, Economic Research Service analysis of customs data for pork-exporting countries accessed through the Trade Data Monitor.

The capacity of EU countries to supply more pork to China was constrained by the spread of ASF in Europe. By 2018, China had already banned pork imports from EU countries Italy, Hungary, Poland, Belarus, Romania, and Belgium (see table A.1). China banned pork from Slovakia in 2019 and from Greece in 2020. In September 2020, China suspended pork imports from Germany—one of the top two EU pork exporters—due to ASF outbreaks. Major EU exporters Spain, Denmark, and France remained free of ASF.

EU pork exports to China grew from 1.28 million metric tons to over 3.1 million metric million tons during 2018–20 (table 7). EU countries exported a cumulative total of more than 9 million metric tons of pork to China during 2018–21.

The United States was the second leading exporter of pork to China (after the EU), despite a series of Chinese tariffs imposed during 2018 as U.S.-China trade tensions coincided with China's ASF outbreaks. In April 2018, China imposed a 25-percent tariff on U.S. pork in response to U.S. tariffs imposed on Chinese steel. In July 2018, China added another 25-percent tariff on U.S. pork to retaliate against another round of U.S. tariffs. The total tariff on U.S. pork products rose to 62 percent for the most-imported pork products. U.S. pork exports got a boost after the February 2020 Phase One U.S.-China Economic and Trade Agreement committed China to increase its purchases of U.S. products. After the agreement was signed, Chinese authorities allowed importers to apply for exclusions from one of the 25-percent tariffs. U.S. pork exports to China grew from 186,500 metric tons to 955,670 metric tons during 2018–20 (table 7).

Brazil became the third leading pork exporter to China as its exports grew from 156,200 metric tons in 2018 to 532,000 metric tons in 2021 (table 7). Brazil's pork exports to China grew despite China's suspension of the import permit of a Brazilian pork processing plant due to COVID-19 outbreaks in the country and rejections of multiple Brazilian meat shipments due to the detection of the COVID-19 virus by Chinese customs inspectors (Reuters, 2021b).

Table 7
Pork exports to China by major exporting countries and regions, 2018–21

Exporters	2018	2019	2020	2021	2018–21 total
			1,000 metric tons		
European Union	1,280.2	2,156.0	3,142.8	2,474.1	**9,053.2**
United States	186.5	533.5	955.7	682.0	**2,357.6**
Brazil	156.2	250.7	513.2	532.0	**1,452.0**
Canada	280.6	251.6	601.0	275.5	**1,408.7**
Chile	72.4	117.9	211.7	177.4	**579.4**
United Kingdom	81.5	131.5	176.1	147.7	**536.7**
Mexico	2.8	30.4	109.0	63.9	**206.0**
Argentina	0.0	1.0	20.6	16.3	**37.9**
Switzerland	0.0	0.1	2.8	3.8	**6.8**
Costa Rica	0.0	0.0	2.1	0.2	**2.3**
Russia	0.1	0.2	0.6	0.5	**1.4**
Australia	0.6	0.3	0.1	0.3	**1.4**
Serbia	0.0	0.0	1.2	0.1	**1.3**

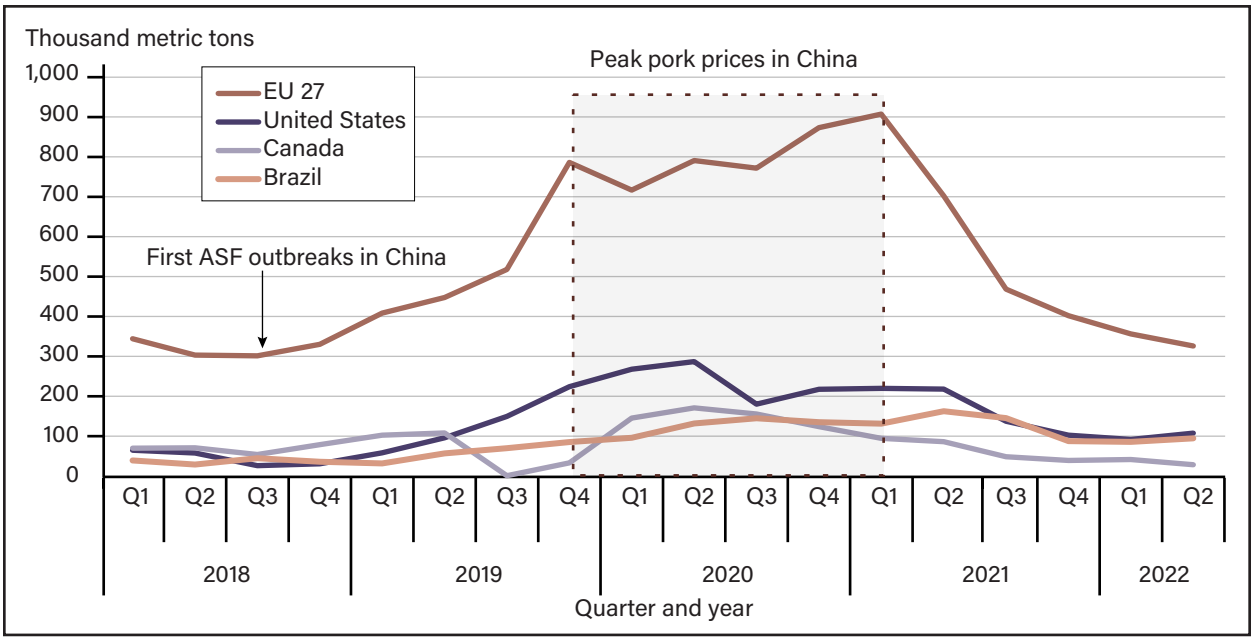
Note: Countries exporting less than 1,000 metric tons are omitted in this table.

Source: USDA, Economic Research Service analysis of customs data from pork-exporting countries accessed through the Trade Data Monitor.

Exporters Saw a Surge in Pork Exports During 2019–20 and a Decline in 2021

Quarterly data show that EU, U.S., and Brazilian pork exports to China began rising in 2019 (figure 14). EU exports rose dramatically in 2019 Q2 as China's pork shortfall reached its maximum. EU exports rose to their peak value in 2021 Q1 at more than 900,000 metric tons. U.S. exports peaked in 2020 Q2 at more than 287,000 metric tons. Canadian exports dropped in 2019 Q3 due to China's 4-month suspension of Canadian meat due to political tensions (Johnson, 2019). Canadian exports then recovered to reach a peak of 172,000 metric tons in 2020 Q2. Brazilian pork exports to China peaked at 165,000 metric tons in 2021 Q2. Pork exports to China by each major supplier dropped in 2021 as China's domestic pork supplies recovered and pork prices plummeted. The drop in EU exports was particularly large. By 2022 Q2, the volume of EU pork exports to China had returned to a level comparable to their pre-ASF level in 2018.

Figure 14
Pork exports to China by leading exporters, 2018–22



Q1, Q2, Q3, and Q4 = quarters 1, 2, 3, and 4. ASF = African swine fever.

Note: EU 27 represents the 27 member states of the European Union.

Source: USDA, Economic Research Service based on customs data accessed through the Trade Data Monitor.

Exports of Higher Valued Muscle Cuts to China Increased More Than Exports of Offal

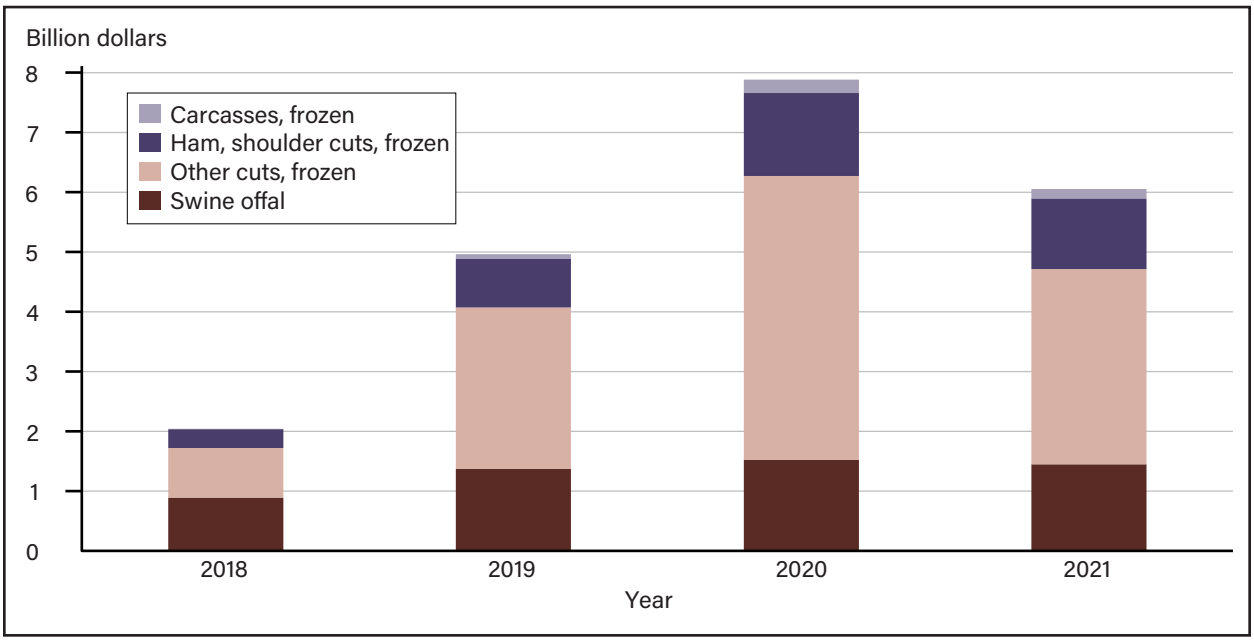
Exports to China of higher valued muscle cuts and entire carcasses increased more than exports of lower valued offal. Tonsor and Luke (2021) noted that low-valued cuts (feet, head meat, organs, tongues, hearts, and skins) normally constitute a large portion of U.S. pork exports to China. In 2018, these items and unspecified offal (Harmonized System or HS category 020641) made up about 40 percent of the value of both U.S. and EU pork exports to China, but their share fell to about 20 percent by 2020 as exports of higher valued muscle cuts accounted for most of the growth. Customs data from the European Union and the United States show that exports of unspecified cuts of frozen pork (HS category 020309) and frozen ham and shoulder cuts (HS 020312) grew rapidly (figures 15 and 16).

Unspecified cuts of frozen pork (mainly muscle meats) accounted for 58 percent of EU pork exports and 44 percent of U.S. pork exports to China in 2020, the peak export year. This category also accounted for more than 95 percent of Brazilian pork exports to China and 70 percent of Canadian exports. The United States had a comparatively smaller growth in exports of frozen ham and shoulder cuts. There were relatively few exports to China of processed pork products such as hams, bacon, salted, smoked, or other prepared products.

There was an unusual increase in sales of entire swine carcasses to China during 2019. Carcasses comprised less than 0.1 percent of U.S. and EU pork exports to China in 2018, but during 2019–20, frozen carcasses (HS 020321) comprised 40 percent of U.S. pork exports to China (by value). This increase reflects the

retooling of at least one U.S. Smithfield Foods plant to produce carcasses for shipment to a plant in China that had excess processing capacity due to the shortage of hogs in the country (Polansek, 2019).[17] The carcass share of EU exports rose to only 3 percent in 2020.

Figure 15
European Union pork exports to China by type, 2018–21

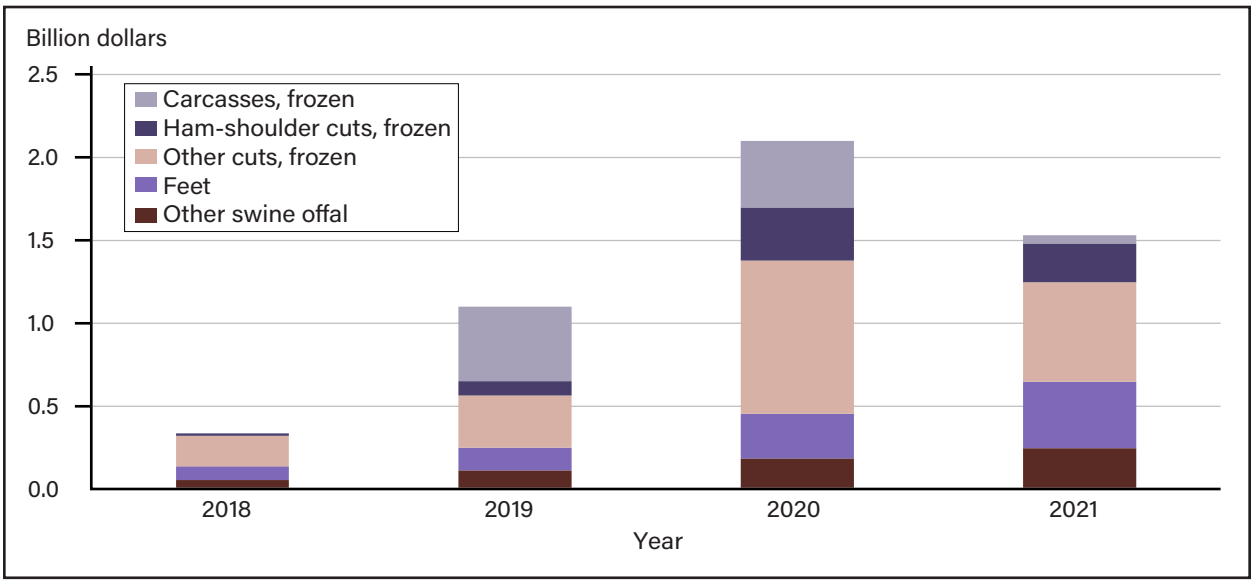


Note: Swine offal is harmonized system (HS) category 020649; other cuts, frozen is HS 020329; ham, shoulder cuts, frozen is HS 020322; and carcasses, frozen is HS 020321.

Source: USDA, Economic Research Service based on customs data accessed through the Trade Data Monitor.

[17] Carcasses include mainly bones and muscles that remain after the removal of internal organs, blood, feet, head, tail, and skin. Shuanghui Development, a company owned by the same holding company as Smithfield, used excess capacity in its Chinese plant to make processed products from the carcasses. Polansek (2021) reported that the U.S. Smithfield plant switched back to processed products in 2021.

Figure 16
U.S. pork exports to China by major type, 2018–21



Note: Categories are composed of the following harmonized system (HS) categories: carcasses, frozen is HS 020321; ham, shoulder cuts, frozen is HS 020322; other cuts, frozen is HS 020329; and feet is HS 0206490030. The category "other swine offal" includes tongues HS 0206490010, hearts HS 0206490020, head meat HS 0206490040, skins HS 0206490050, and other edible frozen offal of swine HS 0206490090.

Source: USDA, Economic Research Service based on customs data accessed through the Trade Data Monitor.

Among Leading Pork Exporters, Canada Was the Most Reliant on Exports to China

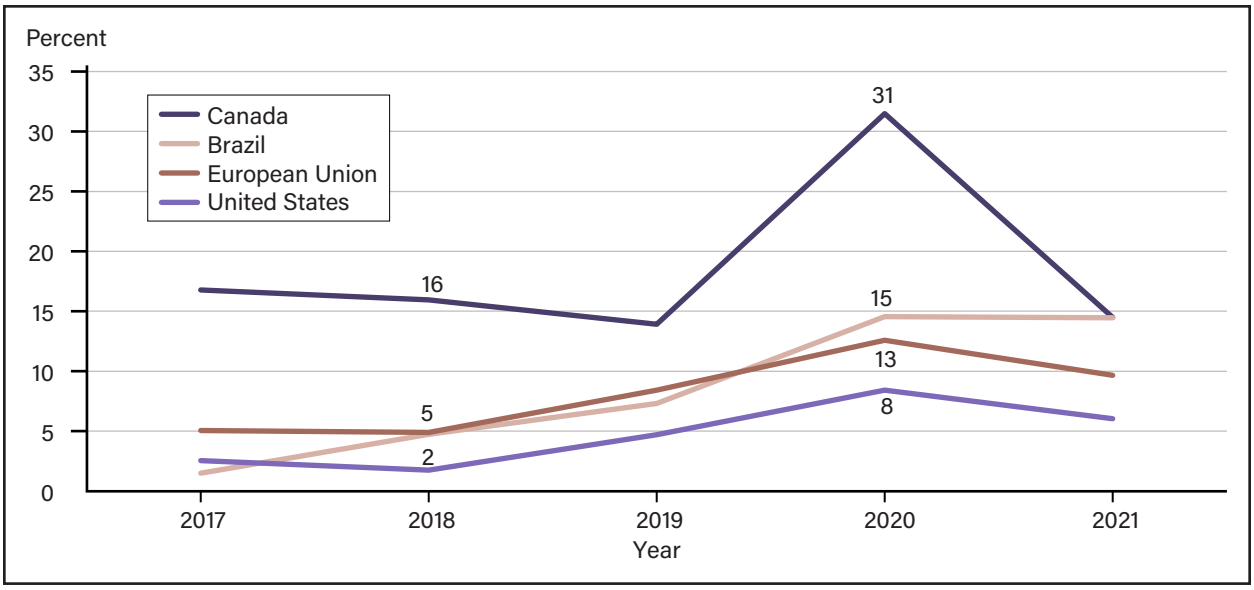
The authors gauged the importance of pork exports to China for leading pork-exporting regions (the European Union, United States, Canada, and Brazil) by estimating the share of pork production exported to China during 2018–21. Data from USDA's Production, Supply, and Distribution (PSD) database were used to calculate the ratio of pork exports to pork production for each exporting region.[18] PSD does not report the destination of exports, so Chinese customs data were used to calculate the share of each region's exports destined for China. The resulting ratio is an estimate of the proportion of each region's pork output exported to China from 2017 to 2021.

The ratios indicate that Canada's pork industry was most reliant on pork exports to China (consistent with an assessment by McEwan et al. [2021]), while the U.S. industry was the least reliant (figure 17). The importance of pork exports to China grew for each of the four regions during China's ASF-related pork production shortfall. In 2018, the first year of China's ASF outbreaks, exports to China accounted for 16 percent of Canadian pork production, 5 percent of EU and Brazilian production, and just 2 percent of U.S. production. Each ratio was higher in 2020, the peak year of pork exports to China. That year, pork exports to China accounted for 31 percent of Canadian production, 15 percent of Brazilian production, 13 percent of EU production, and 8 percent of U.S. production. The ratios fell in 2021 for Canada, the EU, and the United States, but the ratios still exceeded their values in 2017 and 2018.[19] The ratio remained steady in Brazil during 2020–21.

[18] The PSD data exclude offal and may therefore understate the proportion of pork exported to China since offal made up a significant share of exports pre-ASF. However, the analysis above showed that the increase in exports to China in 2019–20 was composed mainly of muscle cuts. Thus, the increase in ratios reflects the growing importance of pork exports to China over time.

[19] Calculations using quarterly U.S. pork balance sheet data showed that the share of U.S. pork supply exported to China peaked at about 14 percent during 2020 Q2 and Q3, fell to 9 percent during 2021 Q2, and fell to 4 percent in 2021 Q4.

Figure 17
Estimated share of pork production exported to China by major exporters, 2017–21



Note: Product of ratio of pork exports to pork output and share of pork exports to China.

Source: USDA, Economic Research Service calculations using data from USDA, Production, Supply, and Distribution database and Trade Data Monitor.

Exporters' Pork Price Increases Were Not as Big as China's Price Increases

Many industry analysts anticipated that China's increased demand for pork would drive up prices in the global pork market as more pork was diverted to China. Mason-D'Croz et al. (2020) used a global general equilibrium model to estimate that world pork prices would rise 17–85 percent. During 2018–19, as producers in the United States and Europe heard news of an impending increase in pork exports to China, prices began to rise to varying degrees, and there was some expansion of production capacity. However, the impacts on exporter prices were relatively brief and offset by declining exports to other markets. As exports to China peaked in 2020, the COVID-19 pandemic became a new source of uncertainty in pork markets. During 2020, market analysts were already expecting a decline in exports to China based on news of China's pork industry recovery (Flach, 2020).

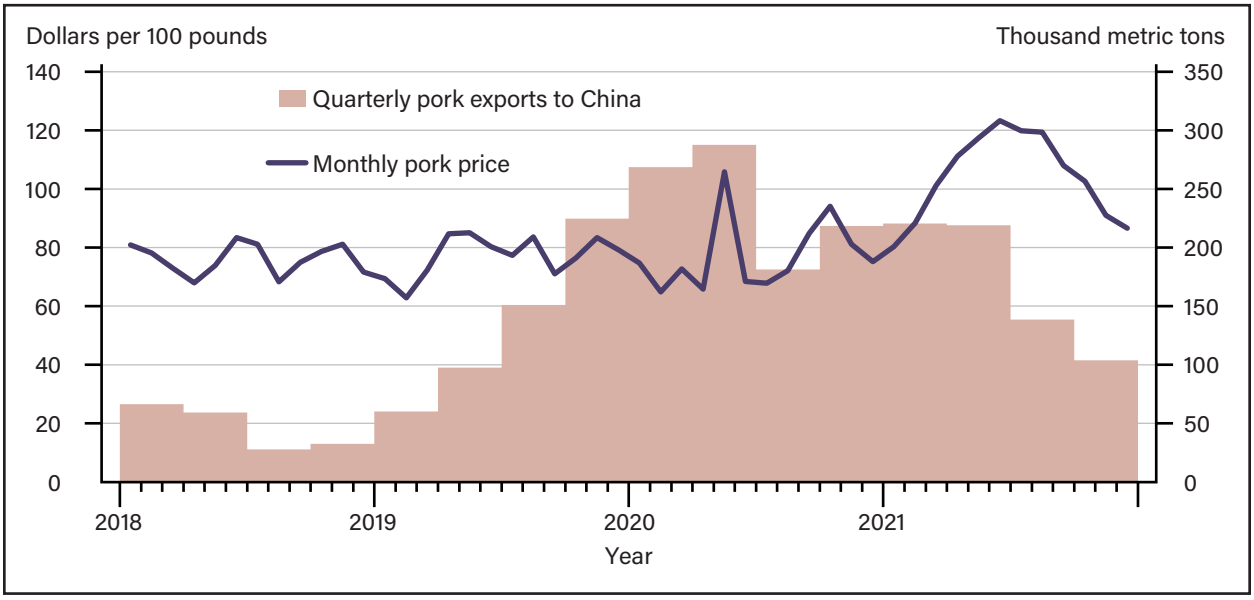
Figure 18 displays monthly pork prices from 2018 to 2021 for the United States and figure 19 for Spain and Germany, the top EU pork-exporting countries. Quarterly pork exports to China are shown alongside prices in each chart to assess how price dynamics corresponded to changes in export shipments to China. Price impacts on the United States, Spain, and Germany are more difficult to discern than the more-than-doubling of pork prices observed in China during 2019–20.

The surge of U.S. pork exports to China came after several years of low U.S. pork prices dating to 2014 (Balagtas & Cooper, 2021), while production and inventory had been steadily increasing to record numbers. A sharp increase in U.S. pork prices occurred during February–April 2019, driven by expectations of a surge in pork exports to China. However, pork prices weakened during the second half of 2019 and did not follow the usual seasonal pattern of rising to a peak during the summer months that year. A market analyst explained that the increase in pork shipments to China during the first half of 2019 was less than expected and offset by a decline in exports to Mexico. Exports to China in the first half of 2019 were up 27 percent from the previous year but still accounted for just 2 percent of U.S. pork production (Plain, 2019). Later in

2019, another analyst attributed a sharp decline in U.S. hog futures prices to disappointing sales to China (Meyer, 2019). Another market analyst suggested that the expansion of the U.S. swine herd had been spurred during 2018 by expectations of greater demand from China (Schulz, 2019).

Flach (2019) attributed an increase in piglet and carcass prices in Europe in 2019 to rising exports to China. Durisin (2019) noted that Europe's tighter supply situation led to stronger price increases than in the United States. Spain benefited the most from China's increased demand as its exports to China doubled in 2019—accounting for 18 percent of Spain's pork output.

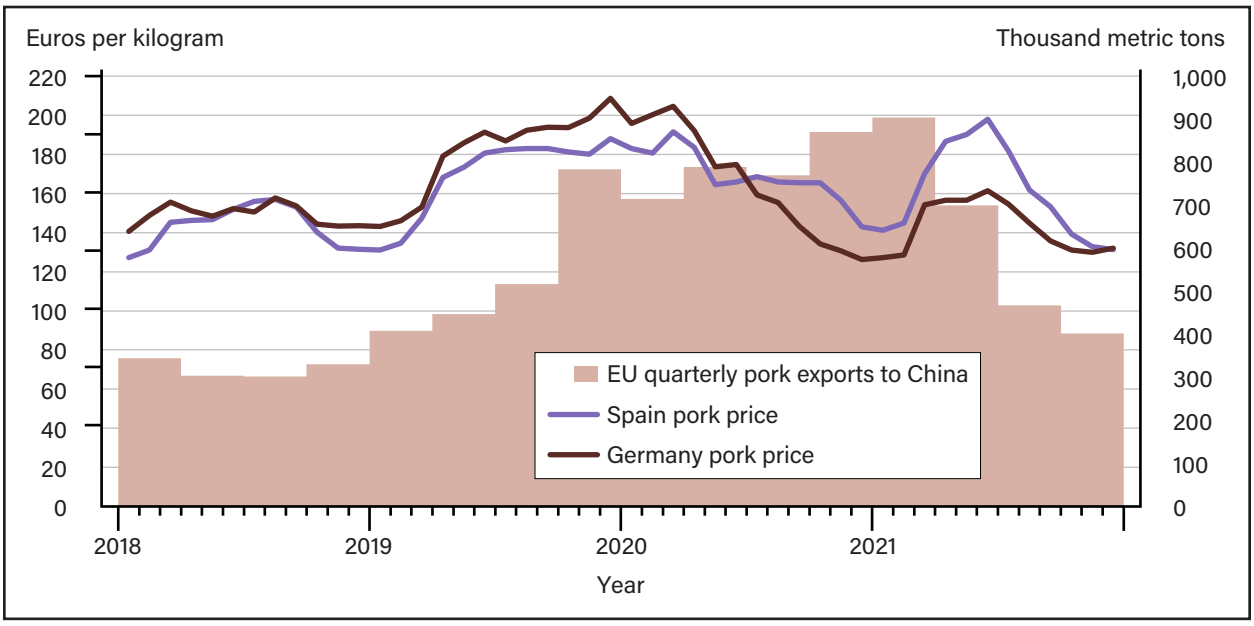
Figure 18
U.S. pork price and exports to China, 2018–21



Note: Pork price is wholesale pork cutout.

Source: USDA, Economic Research Service calculations based on information from the Trade Data Monitor.

Figure 19
Pork prices in Spain and Germany, and European Union (EU) pork exports to China, 2018–21



Note: Average carcass price, class "superior."

Source: USDA, Economic Research Service based on information from the European Commission, Agriculture and Rural Development website and the Trade Data Monitor.

Coronavirus (COVID-19) Pandemic Masked Impacts of Exports to China

China's imports of pork peaked in 2020, but the impact of the COVID-19 pandemic and the spread of ASF to Germany made it harder to discern the impact on pork-exporting countries (Strak, 2020).

During 2020, surging COVID-19 infections concentrated in China's Wuhan City prompted widespread lockdowns and a disruption of logistics. Pandemic outbreaks in Europe, North America, and South America prompted Chinese authorities to suspend shipments from some exporting plants, and Chinese officials issued requirements for exporters' plant layouts and sanitation practices. Plants in several exporting countries were suspended by Chinese authorities to export pork to China or voluntarily suspended sales to China due to COVID-19 infections or staffing problems in mid-2020 (McEwan et al., 2021; Flach, 2020; Vaiknoras et al., 2022). In the second half of 2020, Chinese authorities adopted measures to disinfect, test, and segregate imported frozen foods as they entered China, raising the cost of handling imported meat (Hirtzer, 2021). U.S. and Canadian pork exports to China declined, coinciding with the adoption of these measures, but exports of EU and Brazilian pork continued to increase.

Hog inventories were higher in Europe and the United States in early 2020. However, the scaling back of processing due to COVID-19 outbreaks resulted in a brief spike in pork prices. This development led to a backlog of hogs that could not be slaughtered, depressing live hog prices. The demand for various cuts of pork was altered by U.S. consumers' shift in spending from restaurants to food purchases for at-home consumption (Vaiknoras et al., 2022).

Pork prices in the United States rose sharply during the first half of 2021 as demand was spurred by stimulus income, along with cost pressure from rising feed and energy prices and rising wages (Lusk & Tonsor, 2022). Pork exports to China remained strong during early 2021 and may have contributed to overall tightness in the U.S. pork market.[20]

The first ASF outbreaks in Germany during September 2020 caused German prices to drop after China, Japan, and South Korea banned German pork. While EU pork exports to China during the first half of 2020 doubled from a year earlier, exports to other destinations were down 25 percent (Flach, 2020). During 2021, Spanish and U.S. pork prices followed similar patterns of increase during the first half of the year, which seemed to reflect tightened hog supplies and inflationary pressure from raw material prices and wages. U.S. pork shipments to China began falling in the second half of 2021. China's demand for imported pork was likely curbed by the combination of falling prices in China and rising prices in exporting countries.

Summary of Impacts

After reaching China in 2018, ASF spread rapidly within the country, resulting in an estimated loss of 27.9 million metric tons of pork production over 30 months from 2018 to 2021. The loss represented 18 percent of "normal" pork output that might have occurred without the epidemic. China imported a record volume of pork, but the increased amount of imports replaced only one-fifth of the production lost to ASF. Thus, the total supply of pork in China declined significantly.

Chinese consumers experienced much higher pork prices. China's consumer pork prices rose by 109 percent and remained at record levels for 14 months from November 2019 to January 2021. The proportionately smaller decline in pork consumption during 2019–20 (approximately 23 percent) implies that China's pork demand is price inelastic. Some of the pork consumption decline was offset by increased consumption of other meats and seafood.

Note that the impacts described in this report reflect China's status as a pork importer. An ASF outbreak in a pork-exporting country might have an even larger impact on producers. For example, Rehder (2020) reported the likelihood of ASF reaching Germany had already affected German pork exports a year before the first cases were discovered there. As pork exports were curtailed after ASF outbreaks in Germany in 2020, German pork prices decreased faster than in Spain, which was still free of ASF.

China's pork shortfall seems to have had a relatively brief impact on the world market. Canada, Brazil, the European Union, and the United States increased the share of pork exported to China, and at least one U.S. pork-producing plant was retooled to temporarily send entire carcasses to China. However, the volume of pork diverted to China was not large enough to cause a discernible or sustained rise in pork prices in exporting countries. Some farms expanded their production capacity in 2019 to meet expected demand in China (Schulz, 2019), but prices did not rise enough to prompt farms and processors to make long-term investments in capacity. Chinese data indicate production recovered to its pre-ASF level in the first quarter of 2021. China's pork prices fell by about 50 percent that year and returned to their pre-ASF level by September 2021, about 3 years after the first outbreaks occurred. China's pork imports fell rapidly as domestic production recovered in 2021, but imports still exceeded their pre-ASF level at the end of that year. Household pork consumption data indicate a strong recovery in 2021, consistent with the rapid rebound in pork supply.

[20] About 9 percent of U.S. pork was exported to China in the second quarter of 2021.

While the market impacts of the initial African swine fever outbreaks dissipated rapidly, the virus continued to play a role in the changing structure of China's pork industry. Zhang et al. (2021) described the rapid consolidation of capital-intensive pork producers in China before and during the ASF epidemic. An influx of investment that contributed to China's rapid recovery was focused on large-scale farms of publicly listed companies that had better access to capital markets and bank credit than individual operators. This trend was encouraged by Government support policies that focused on such farms, in part because authorities expected these farms to adopt strict biosecurity practices observed by Hess (2020) that would prevent future disease outbreaks.

ASF nevertheless continued to affect China's hog producers. In November 2022, China's Ministry of Agricultural and Rural Affairs instructed farmers to disinfect farm facilities and take other precautions as the risk of ASF rose during the winter, and there were debates about the extent of new ASF outbreaks during March 2023 (*National Business Daily*, 2023). As of 2023, companies reported investing in capital-intensive farms and taking stronger precautions to deal with the spread of the ASF virus (Zeng, 2023).

Improvements in biosecurity (including veterinary expenses, disinfection, as well as the construction of capital-intensive farms designed to reduce the risk of viruses and other pathogens entering the premises) added to production costs. To the extent that rising pork prices in China reflected rising production costs (Gale, 2017), lower prices for imported pork may sustain the demand for imported pork, despite the expansion of pork production capacity in China. At the same time, increased pork market volatility in China has continued after the ASF epidemic, which may create additional uncertainty for pork exporters. Thus, the spread of ASF to China may have lasting impacts on the global pork market despite China's rapid recovery.

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Appendix Tables

Table A.1
Countries whose pork was banned by China due to African swine fever outbreaks, 2018–22

Region	Country	2018	2019	2020	2021	2022
		x=country's pork products banned by China				
Europe	Georgia	x	x	x	x	x
	Italy	x	x	x	x	x
	Malta	x	x	x	x	x
	Lithuania	x	x	x	x	x
	Estonia	x	x	x	x	x
	Latvia	x	x	x	x	x
	Belarus	x	x	x	x	x
	Russia	x	x	x	x	x
	Ukraine	x	x	x	x	x
	Moldova	x	x	x	x	x
	Bulgaria	x	x	x	x	x
	Czech Republic	x	x	x	x	x
	Hungary	x	x	x	x	x
	Poland	x	x	x	x	x
	Romania	x	x	x	x	x
	Belgium	x	x	x	x	x
	Serbia		x	x	x	x
	Slovakia		x	x	x	x
	Germany			x	x	x
	Greece			x	x	x
	North Macedonia					x
Asia	Armenia	x	x	x	x	x
	Azerbaijan		x	x	x	x
	Myanmar		x	x	x	x
	Laos		x	x	x	x
	Vietnam		x	x	x	x
	North Korea		x	x	x	x
	Cambodia		x	x	x	x
	Mongolia		x	x	x	x
	Indonesia			x	x	x
	India			x	x	x
	Malaysia			x	x	x
	Philippines			x	x	x
	South Korea			x	x	x
	Timor-Leste			x	x	x
	Bhutan				x	x
	Thailand					x
	Nepal					x

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Region	Country	2018	2019	2020	2021	2022
		x=country's pork products banned by China				
Oceania	Papua New Guinea			x	x	x
Africa	Botswana	x	x	x	x	x
	Madagascar	x	x	x	x	x
	Senegal	x	x	x	x	x
	Ghana	x	x	x	x	x
	All of Africa		x	x	x	x
Americas	Dominican Republic					x
	Haiti					x

Source: USDA, Economic Research Service compiled using data from the China General Administration of Customs, 2018–22.

Table A.2

African swine fever cases in Chinese Provinces, 2018–22

Province	2018	2019		2020		2021		2022	Total
	July–Dec.	Jan.–June	July–Dec.	Jan.–June	July–Dec.	Jan.–June	July–Dec.	Jan.–June	
Anhui	802								**802**
Beijing	224								**224**
Chongqing	11	9	1		14		1		**36**
Fujian	147			3		2			**152**
Gansu		187	265	486					**938**
Guangdong	52								**52**
Guangxi		1,663	104						**1,767**
Guizhou	80	179					1		**260**
Hainan		432					9		**441**
Hebei		107							**107**
Heilongjiang	5,044								**5,044**
Henan	178			252					**430**
Hubei	62	91	14	169		10	104		**450**
Hunan	459	270				3			**732**
Inner Mongolia	126					381			**507**
Jiangsu	627	2,452		10	4	6			**3,099**
Jiangxi	75								**75**
Jilin	208								**208**
Liaoning	2,385		22						**2,407**
Ningxia		31	13						**44**
Qinghai	14	32							**46**
Shaanxi	309	150		39					**498**
Shandong		17		1		214			**232**
Shanghai	50								**50**
Shanxi	176								**176**
Sichuan	197	120	36	25		38			**416**
Tianjin	359								**359**
Tibet		263							**263**
Xinjiang		204				346		16	**566**
Yunnan	551	288	235	81	14				**1,169**
Zhejiang	486								**486**

Source: USDA, Economic Research Service compiled using data on the World Organisation for Animal Health web site.

Table A.3

Changes in per capita pork consumption, by Chinese Province, 2018–21

Province/region	Change, 2018–20	Province/region	Change, 2020–21
	Kilograms		Kilograms
Hainan	-12.4	Hainan	11.6
Sichuan	-10.9	Liaoning	9.8
Guangxi	-10.6	Chongqing	9.7
Fujian	-9.8	Guangxi	9.7
Chongqing	-8.9	Zhejiang	9.4
Guangdong	-8.0	Heilongjiang	9.4
Hunan	-7.1	Hunan	9.3
Guizhou	-6.8	Hubei	8.7
Jilin	-4.7	Jilin	8.6
National average	**-4.6**	Inner Mongolia	8.5
Anhui	-4.0	Fujian	8.4
Zhejiang	-3.7	Sichuan	8.3
Hubei	-3.5	Shandong	8.0
Heilongjiang	-3.5	Henan	7.9
Shandong	-3.5	**National average**	**7.6**
Shanghai	-3.3	Hebei	7.1
Jiangsu	-3.1	Jiangsu	7.0
Hebei	-2.9	Jiangxi	6.4
Yunnan	-2.8	Yunnan	6.1
Tianjin	-2.7	Guizhou	5.9
Henan	-2.6	Anhui	5.9
Liaoning	-2.5	Gansu	4.9
Gansu	-2.4	Qinghai	4.9
Qinghai	-1.7	Shanghai	4.0
Inner Mongolia	-1.7	Shaanxi	4.0
Shaanxi	-1.3	Guangdong	3.6
Ningxia	-1.2	Tianjin	3.5
Shanxi	-1.1	Beijing	3.2
Beijing	-1.0	Shanxi	3.0
Jiangxi	-0.6	Ningxia	2.2
Xinjiang	-0.3	Xinjiang	1.6
Tibet	0.0	Tibet	-0.5

Note: Data are from a Chinese national household survey; excludes consumption away from home.

Source: USDA, Economic Research Service calculations using data from the China National Bureau of Statistics, *China Statistical Yearbook.*