AN ANALYSIS OF AFRICAN SWINE FEVER CONSEQUENCES ON RURAL ECONOMIES AND SMALLHOLDER SWINE PRODUCERS IN HAITI

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AN ANALYSIS OF AFRICAN SWINE FEVER

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Abstract: African Swine Fever (ASF) causes high mortality, and often results in strict culling policies for affected pigs and international market restrictions. It took more than 25 years for swine inventories in Haiti and the Dominican Republic to recover from an ASF outbreak in 1978-1984. The 2021 outbreaks in the Dominican Republic and Haiti pose threats to animal health, livestock markets, and producer livelihoods.

A partial equilibrium Haitian pig sector model (HPM-2021) was developed to assess the economic impacts of a 2021 Haitian ASF outbreak of a similar size to the 1980s outbreak. The dynamic model examines ASF impacts from 2021 to 2024, through 100 iterations of stochastic supply shocks, and three specific demand shocks. Recovery alternatives are assessed through 2030.

Outbreaks and recovery outcomes are compared to a baseline reflecting 2019 trends. Findings demonstrate higher vulnerabilities of the traditional sector to ASF-related disruptions. The inflated prices generated by pork production shortfalls are an opportunity to accelerate income growth for remaining traditional pig producers. ASF supply-only shocks contribute to a minimum of 49% increase in traditional producer income, and a minimum of 2.22% growth in commercial producer income from the 2019 base year. Nevertheless, the potential for consumer avoidance of pork offset those gains by as much as 90% in the traditional sector and 44% in the commercial sector. Smaller commercial sector impacts derive from different elasticities. The analysis includes economic effects on national pork and maize in Haiti, the Dominican Republic, the rest of the Caribbean, and the rest of the world.

ASF-induced high prices also lead to increased consumer expenditures losses by up to 200%. Nevertheless, consumers’ expenditures tend to recover instantaneously with ASF eradication. Due to persisting demand shocks, producers will earn up to 0.3% lower than baseline levels income from 2027.

There are few models that evaluate economic impacts of health response policies in less developed countries like Haiti. HPM-2021 results highlight ASF impacts on prices, which can benefit certain producers and disincentivize on-farm disease reporting. Slow recovery and consumers’ avoidance of pork is detrimental to long-term swine industry survival, producer livelihoods, and the overall rural economy.

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CHAPTER I

INTRODUCTION

In 2021, nearly four decades after a 1980's high-cost African Swine Fever (ASF) eradication effort, the USDA Foreign Animal Disease Laboratory confirmed new ASF cases on the Hispaniola Island (USDA APHIS, 2021). Outbreaks were confirmed in the Dominican Republic in July by the USDA Foreign Animal Laboratory from samples collected in May. The first infections were confirmed in the northeastern provinces, near the Haitian border. This proximity raised concerns about the risks of swine infection in Haiti, where swine production remains a crucial economic sector. In September, tests carried out by the Plum Island Disease Center confirmed ASF cases in Haiti's Northwest department (Net, 2021). By December 2021, the virus had been detected in 28 of 31 Dominican provinces and the Northern departments of Haiti. According to the Organisation Internationale des Epizooties (OIE), the detected ASF-infected pigs have been immediately slaughtered, and zoning has been applied, with surveillance of the containment zone (USDA APHIS, 2021; Net, 2021).

The last ASF outbreak on Hispaniola Island was in 1978-1984. Haitian smallholder swine farmers experienced long-lasting hardships due to the lack of diversification in their income and asset portfolios (Ebert, 1985). Before the first ASF outbreaks, indigenous "creole" pigs were the most plentiful farm animals. Over 80% of Haiti's population lived in rural areas, and 95% of them were smallholder swine producers. For most owners, pigs were an important source of wealth and cash income. Income from pig sales have often been used to finance planned events and for emergency expenditures (Alexander, 1992). Although creole pigs were relatively small — usually not exceeding 150 pounds — they constituted the backbone of the rural Haitian economy. Rural areas highly benefited from their low production costs (Gaertner, 1990). Four decades after a costly ASF eradication, the Haitian swine sector still has not completely recovered production levels from the 1978-1984 ASF outbreaks.

Much has changed in the global swine market and in policies for disease eradication, yet the Haitian swine industry structure is still very similar to the 1970s (Ayodeji, 2014). In rural areas, the traditional production system is dominant, with low biosecurity and disease prevention measures. Pigs continue to play a major role in reducing food insecurity, maintaining soil fertility, and empowering social equality. Prior to the 2021 ASF discovery, Haiti already faced challenges of food insecurity, unemployment, and high vulnerability to social and natural hazards. Economic and social development continued to be hindered by political instability (IMF, 2013). Consequently, the country has one of the lowest Human Development Index scores (0.51) and GDP per capita ($1149 per year). According to the World Bank, the COVID-19 pandemic further deepened the economic contractions reported in the previous years (World Bank, 2021). The recent socioeconomic challenges emphasize the need of applying efficient ASF control measures in the current outbreak that preserve swine producer livelihoods. During the last five years, pigs have contributed up to 11% of the total domestic livestock output. More than 70% of Haiti's rural population raise pigs today, often in small numbers most commonly for the purpose of wealth creation and an investment against future expenditures (Ayodeji, 2014).

Many owners rely on swine production for their animal-derived nutrients. Besides being a high-protein food, pork is also a good source of potassium, zinc, phosphorus, and vitamin B6, which are crucial elements for fighting chronic nutrient deficiencies (Narod et al, 2012). Despite the importance of the swine industry in the overall economy, smallholder producers often lived in rural communities lacking consistent access to essential services. In 2019, rural areas received only 15% of the country's electrical power, 16% of the modern health facilities, and 20% of the education-related expenditures (World Bank 2021; UNESCO, 2021).

Research Objective

Although there is a need to assess the impact of ASF discovery today, as well as identify suitable eradication policies, there are no models of the Haitian pig sector and limited literature on ASF response in smallholder pig production (Ouma et al., 2018; Nguyen et al., 2021). The purpose of this research is to assess the economic consequences of the 2021 ASF outbreaks to swine production and consumption, and the cost-effectiveness of prospective control measures in Haiti. The Haitian Pig Sector partial equilibrium model (HPM-2021) was developed to simulate the dynamic effects of ASF and adopted control measures. The research consists of a baseline (no-outbreak) scenario that projects the 2019-2020 changes in production, consumption, and prices of traditional pigs, commercial pigs, and maize through 2030. The economic impacts of ASF are estimated through numerous alternative scenarios based on Haiti's previous experiences with ASF, and policies applied by other affected countries in the past.

The paper explains ASF's first introduction in Haiti in 1978 and the creation of the Projet pour l'Eradication de la Peste Porcine Africaine et pour le Développement de l'Elevage Porcin (PEPPADEP) in 1981. The PEPPADEP was launched by the Government of Haiti (GOH), in collaboration with the governments of Canada, Mexico, and the United States, the Food and Agriculture Organization of the United Nations (FAO), the Inter-American Institute for Cooperation on Agriculture (IICA), and the Interamerican Development Bank (IDB). The analysis of the 1980's outbreaks in Haiti and international ASF eradication experiences lay out the conditions to simulate the impacts of ASF-related shocks in HPM-2021. The quantitative results describe the potential effects on livelihoods from the 2021 ASF outbreaks. The outcomes may enhance development of measures that could cost-effectively decrease ASF consequences to producers. Finally, the study includes an analytical framework that examines alternative policies, not pursued by the PEPPADEP, to reconstitute the Haitian swine industry after the 2021 outbreak.

CHAPTER II

LITERATURE REVIEW

Background of ASF Infection

Among various Transboundary Animal Diseases (TAD) affecting swine, ASF is one of the most detrimental for infected livestock populations. ASF is a complex and viral hemorrhagic disease of swine with a high mortality rate for infected animals. The disease is caused by a DNA virus (ASFV) belonging to the Asfarviridae family (Costard et. al, 2013). No curative or preventive measure has been developed for ASFV. Mortality rates may vary based on the disease virulence and the type of infected pigs. In the peracute and acute forms of ASF, hosts often show symptoms of high fever, depression, anorexia, hemorrhages in the skin, vomiting, diarrhea, and even abortion in pregnant sows, with mortality rate being as high as 100% (Costard et. al, 2013; Sanchez-Cordon et. Al, 2018). In the subacute and chronic forms, the clinical signs are less intense, and often last longer than the acute form. Mortality rates range between 30% and 70%, with higher consequences for younger pigs (Sanchez-Cordon et. Al, 2018). The pigs that survive usually become carriers and constitute an active risk of transmission to other healthy pigs. These factors make ASF a disease of concern, and it is listed as a OIE Tier 1 disease threat.

ASFV often spreads through direct contact with domestic and wild pigs. Contamination may also occur through indirect contact with other materials such as food wastes or garbage, human, and biological vectors such as soft ticks of the genus ornithodoros (Alonso, 2013). Despite recent optimistic progress, a vaccine is yet to be effectively developed against ASF (Shike, 2021). Nevertheless, the disease constitutes no direct biological risk to humans. Because of ASF high virulence and the multiple contamination cycles, the epidemiological characteristics of ASF differ in various infected countries.

ASF is mainly found in Sub-Saharan Africa where it remained endemic after the first detection in the 1920s (Gallardo et al, 2017). Before expanded trade and travel facilitated transboundary disease spread, the worldwide swine industry expected that oceans would constitute an outstanding biosecurity barrier preventing the virus from conquering foreign territories. Nevertheless, through extended human travels and international trade, the African Swine Fever Virus (ASFV) managed to spread in several countries. In the second half of the 20th century and later, ASF spread to Mongolia, Vietnam, and parts of the European Union (Allaway et al, 2019). In the 1970's, the first ASF outbreaks in the western hemisphere were discovered in numerous Caribbean countries and Brazil.

At the turn of the 21st century, ASF had been eradicated in various European, South American, and Caribbean countries through the application of aggressive eradication measures and consolidated contingency plans. Stamping out ASF is typically a complicated process for countries involved. Surveillance and control strategies applied by countries worldwide for ASF eradication often differ, given the size and structure of the swine industry, dispositions for early disease detection, and international trade responses. One of Haiti's closest neighbors, Cuba, experienced ASF twice in the 20th century. During both epidemics, similar control measures were applied. The government, with the army's support, adopted very targeted measures, from identification of infected premises to culling of all sick pigs and nearby healthy pigs, as well as any other animals that may carry the disease even while not susceptible to disease (vectors). The strict quarantine and biosecurity mechanisms facilitated ASF regionalization on both occasions, until complete eradication (Simeon-Negril et. al, 2002).

ASF eradication in Spain was achieved through a restructuration of the swine industry (Bech-Nielsen et. al., 1995). The disease remained endemic in various areas of the Iberian Peninsula for more than three decades. Low levels of biosecurity in the swine production system made eradication difficult. From 1984 to 1995, the government successfully implemented restrictive measures that limited pig movement and modified the pig production structure from family-type to industrial production. This policy fostered biosafety barriers, early detection, and prompt reaction to ASF, but at high costs. The execution of the eradication plan cost the country a yearly average of $11.4 million (Bech-Nielsen et. al., 1995; Danzetta et. al., 2001).

Past ASF experiences indicate that the control policies have greatly influenced eradication timeliness and economic costs to the country. A contiguous culling strategy was not uncommon in the 20th century and early in the 21st century for ASF and other highly contagious diseases. Contiguous culling involves the depopulation of infected premises and surrounding premises. This culling approach was employed in Hispaniola Island and Malta and ensured eradication in less than three years. Contiguous culling was both resource intensive and costly when compensation was paid to farmers (Danzetta et. al., 2001). The 1980's Haitian ASF eradication costed $17 million in four years. The implementation of an efficient repopulation strategy was crucial for the swine industry long-term survival under such an intensive depopulation strategy to prevent the permanent loss of livelihoods.

In contrast, massive depopulation was a less favored option for countries with larger pig stocks. Spain, Portugal, Brazil, and Cuba opted for a targeted depopulation and reinforcement of on-farm biosafety measures (Bech-Nielsen et. al., 1995; Danzetta et. al., 2001; Simeon-Negril et.

al, 2002). Implementation of this strategy usually requires long-term commitment, higher financial investments, and more inter-regional coordinated efforts. This approach facilitates future animal disease prevention.

ASF remains a global threat today. After nearly a decade of low transcontinental contamination, ASF reappeared in Georgia in 2007, and thereafter in neighboring countries such as Russia, Armenia, and Azerbaijan (Chenais et. al., 2019). ASF continued to spread and infected some of the world's top pork producing countries. Both China and Germany reported ASF cases in 2018 and 2020, respectively. Those recent outbreaks and trade responses have influenced global markets by impacting fundamental factors in pork supply and demand, leading to economic losses for countries with ASF infections and opportunities for those free of disease (Ma et. al., 2021). In 2021, Caribbean nations Haiti and the Dominican Republic reported new cases of ASF, which poses a threat to animal health, producer livelihoods, and food availability on the island (USDA APHIS, 2021). Similarly to the 1980's outbreaks, the ASFV presence in Hispaniola is a risk to the more developed North-American countries' swine industry. Much can be learned from examining prior response to ASF in Haiti, and lessons learned from other countries.

The 1978-1984 Haitian ASF Outbreaks

The 1970s represent a historical peak in Haitian pig inventories. Dominican government officials detected ASF in pig herds in 1978. As reported by USAID, ASF was introduced by means of infected meat transported by plane from Mediterranean countries (Interim Swine Repopulation, 1983). Although the authorities rapidly opted for the extermination of the pig population, ASF detection in Dominican Republic raised serious concern to the Republic of Haiti. In the Fall of

1978, the GOH confirmed cases of ASF on the border of Haiti and the Dominican Republic (USDA, 1988).

Villeda et al. (1992) compare the haemostatic defects leading to hemorrhage in the ASFV strain (genotype I) that infected the Dominican Republic and Haiti in 1978, with the strain (genotype II) that spread in Malta during the same period. Investigations confirmed that the mortality rates and severity of clinical observations were higher on Hispaniola Island. In the light of risks that faced swine producers, the Haitian Ministry of Agriculture and the Military decided to enforce containment measures. The Ministry ordered the extermination of all pigs located within 15 km from the border in an aggressive contiguous culling strategy (Energ, 1985). The New York Times reported that more than 28,000 pigs (2% of total production) had been slaughtered between 1978 and 1981 in a systematic effort to contain ASF (Treaster, 1984). No compensation has been allocated to farmers in this first round of depopulation. Due to that lack of incentives to report on-farm disease, along with limited preparedness, biosafety protocols, and educational efforts, ASF extended throughout the country’s nine geographical departments by 1981, causing a crisis in the entire swine sector.

In addition to the ASF prevention challenges, the high virulence and lethality of the current strain threatened to spread to other countries. In particular, the disease threatened Haiti’s northern neighbors, most notably the United States and Canada. These countries were expanding commercial swine industries producing pork and pork products for export markets at the time. These countries had much to lose should the virus enter their borders and potentially impact their multi-billion-dollar swine industries. Ebert (1985) estimated that the United States could face up to $5 billion worth of damages should ASF reach the country. Based on this reality, the governments of Canada, Mexico, and the United States, collaboratively with the American Institute for Cooperation on Agriculture, offered immediate financial support to the Haitian government for the elaboration of an effective ASF eradication plan. The PEPPADEP was initiated in 1981 (Interim Swine Repopulation, 1983).

The GOH launched PEPPADEP with the contribution of North American neighbors, through multiple international organizations such as IICA and USAID. The project consisted of two phases. The first, supported by a budget of $23 million, aimed for the eradication of ASF by 1984 through the extermination of indigenous pigs (USAID Interim Swine Repopulation Project, 1983). The second phase was to reconstitute the swine industry and introduce higher productivity swine breeds. International organizations agreed that smallholder farmers in Haiti would not be able to count on pigs as a sustainable livelihood unless ASF is totally eradicated from the country (USAID Interim Swine Repopulation Project, 1983). Additionally, from the international agricultural community's standpoint, ASF eradication in Haiti was an exceptional occasion to improve the national productivity of swine (USAID Swine Interim Project, 1983). Before ASF was detected in Haiti, the pig population was estimated at 1.6 million, mostly owned by smallholder farmers living in rural areas (FAOSTAT).

According to a USDA serological survey, 77% of Haiti's territory had confirmed ASF cases prior to PEPPADEP's slaughter program in 1981 (Alexander, 1992). At the completion of the program, a total of 384,391 pigs have been slaughtered for $9,548,860 compensation paid (See Table 1). The PEPPADEP completed the first phase of its mission in 1984. Through restrictive pig movement and massive depopulation, ASF was officially eradicated from the island in 1984 (Alexander, 1992).

Table 1. Summary of Pigs (a) Killed and Compensation Paid during Slaughter from 1981 to 1984 as Part of the PEPPADEP Campaign in Haiti (Alexander, 1992).

	Pigs Slaughtered in head	Compensation Paid (US$)
Adults	168,007	$6,720,280
Young	116,444	$2,328,880
Piglets	99,940	$499,700
Total	384,391	$9,548,860

(a) In 1978 prior to ASF, the total swine inventory in Haiti was 1.6 million total head of swine.

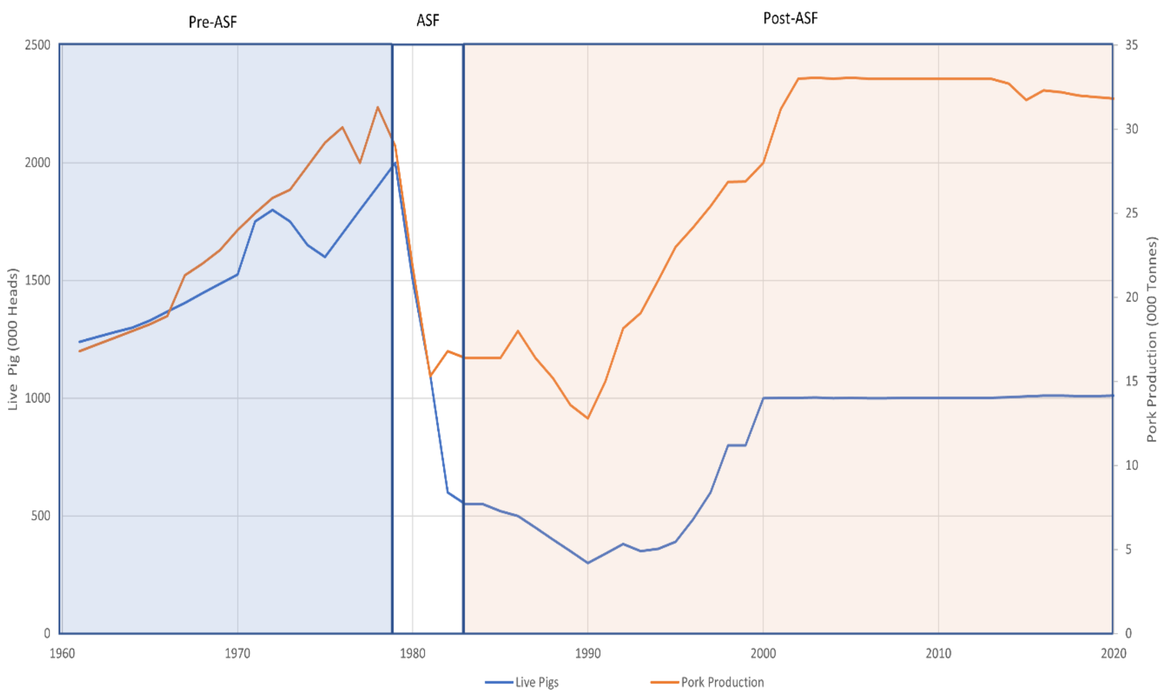
*Source:" Experiences with ASF in Haiti" (Alexander, 1992)

Following ASF eradication, a repopulation program was launched to alleviate smallholder producers who have been economically devastated by the indigenous pigs' extermination and left with limited source of breeding stock. The second phase of PEPPADEP's mission was to import, multiply, and distribute specific-pathogen-free hogs to farmers. Pure lines of Duroc, Yorkshire, Hampshire, and Berkshire were imported from Noth-America. The USAID anticipated many challenges to the repopulation plans:

- The lack of swine holding facilities to be used as secondary multiplication centers.
- The limited well-trained personnel to carry out the project.
- The adaptation of exotic pigs to farmers' poor nutrition methods after distribution (USAID Swine Interim Project, 1983).

Various critics argued that the program failed to redevelop the Haitian swine industry (Gaertner, 1990). Post-ASF data indicate that the country failed to reach pre-ASF live pig volumes four decades after eradication (Figure 1). On the other hand, owing to new breeds' larger size and higher productivity, domestic pork supply (in tonnes) surpassed pre-ASF levels in 2002 and remained stable in the following periods.

Figure 1. Comparison of live pigs and pork processed before, during, and after African Swine Fever in Haiti



*Data source: FAOSTAT (1961-2018)

Figure 1 compares the level of yearly meat processed and live pigs in Haiti from the period preceding 1978's ASF introduction to the decades following the 1984's eradication. In 1978 and 1979, Haitian processed pork and live pig both reached record volumes. ASF-related losses caused a rapid decline in pig population and meat shortfalls throughout the country. In the six years leading to eradication, live pigs and meat processed dropped by 71% and 43%, respectively (FAOSTAT, 1984-1990). Imported pork helped offset effects for consumers, but the impacts for producers were significant.

The post-ASF period data demonstrate the difficulties to reconstitute the swine industry. The massive loss of Haiti's indigenous breeds has had detrimental socio-economic impacts on smallholder producer livelihoods as evidenced by indicators such as nutrition security, income, and social equality (Alonso, 2013; Sánchez-Cordón et. Al., 2018). The PEPPADEP's swine repopulation initiatives began in 1985, with the distribution of improved breeds. Adverse feeding and veterinary practices on Haitian farms adversely impacted the new breeds' well-being. Some of the breeds were not suited for yearly high temperatures. Also, certain Haitian cultural celebrations and voodoo ceremonies required totally black pigs. This served as a motive for farmers' refusal of white Yorkshires, white-striped Hampshires and red Durocs.

These impediments particularly hindered the PEPPADEP's swine repopulation efforts. Consequently, live pigs and meat processed continued to decrease, and the post-ASF averages remained lower than the previous periods. In addition to a direct effect on meat availability, the post-ASF period was marked by worsening socioeconomic conditions in rural areas. ASF-related income losses caused a 14% drop in primary school enrollment, and food insecurity reached 47% (Unesco Institute for Statistics, CNSA, 1985-1999). The drop in living standards induced an acceleration of rural out-migration. Two decades after ASF discovery, the rural share of total population declined by 15% (FAOSTAT, 1985-2005). Haiti's experience with ASF suggests that smallholder swine farmers, hit by the outbreaks and eradication procedures, struggled to recover. The new (2021-2022) outbreak of ASF also threatens the Haitian Swine industry. This study uses the lessons learned from historical outbreaks and a new modelling framework to examine the potential impacts of the 2021-2022 outbreak.

CHAPTER III

METHODOLOGY

HPM Description

The Haitian Pig Model (HPM-2021) is an adaptation of the International Livestock Research Institute's (ILRI) Vietnam pig model that is used to quantify the dynamic effects of ASF infection and control policies at sector level (Nguyen et al, 2021). It is a three-sector, four-region, partial equilibrium model that investigates the dynamics of traditional pigs, commercial pigs, and their interactions with maize, from the supply and demand perspective. Smallholder pigs, often raised for meat and sold in rural traditional wet markets, are classified in the 'traditional pig' sector. Data from 2019 show that this sector accounts for nearly 80% of total pigs supplied in Haiti and is a substantial source of employment for rural populations. Pigs raised in larger farms, often located in urban and suburban areas, by commercially oriented producers are categorized as the 'commercial pig' sector.

Various studies, in the past, have used multimarket or multicommodity models to assess market effects of negative disease shocks on the supply of livestock within a country or region (Nguyen et. al., 2021; Johnson et. al., 2017, Rich and Winter-Nelson, 2007). Multimarket partial equilibrium models may also serve to capture animal diseases' shocks and mitigation effects on related sectors, such as feed. HPM-2021 investigates direct impacts of ASF on swine populations and indirect impacts of ASF shocks on maize, used for both human and animal consumption. The study examines ASF impacts to supply and demand in Haiti and the Dominican Republic, through their trade interactions with the rest of the Caribbean and the rest of the world.

HPM-2021 is developed within the General Algebraic Modeling System (GAMS) framework. The model is used to simulate changes in the swine industry from 2019 to 2030. A base year of 2019 is selected in order to reduce noise in the calculated parameters due to COVID-19 impacts on the international economy. ASF spread and mitigation are assessed in five different demand and supply scenarios. Those shocks are distributed across the 2021-2024 period. The following sections describe the theoretical model, data, and scenarios.

Structural Form

HPM-2021 uses the mixed complementarity problem (MCP) applied in GAMS as outlined in Rutherford (1995). MCP accommodates economic research for markets, allowing economic equilibrium model as systems of nonlinear equations or inequalities, which are difficult to formulate in an optimization context. Our model employs a double-log specification for the supply and demand functions following Nguyen et al. (2021). Because HPM-2021 estimations are based on different own and cross-price elasticity coefficients, the double-log functional form is convenient to explain the potential impacts of an expected percent change in a predictor to a response variable. The core equations are described in the following series of equations.

1. Domestic maize supply functions

Maize supply is a function of area (equation 1) and yield (equation 2). Maize will subsequently be used for both human consumption and animal consumption. For the purposes of this study, the sum of human consumption of domestic maize and swine consumption of domestic maize will equal total domestic maize production; however, this assumption is controlled in the structure of the feed and food equations described in the following sections (equations 7 and 9). Maize demand for both feed and food can also include imported maize. These are defined in (11) and (12).

$$log(A_{rt}) = \alpha_{rt} + \varepsilon_{1_r}^{maize} \times log\left(P_{rt}^{maize}\right) + \sum_l (\varepsilon_{1_{lr}}^{swine} \times log\ (P_{lrt}^{swine})) \quad (1)$$

$$log(Y_{rt}) = \gamma_{rt} + \varepsilon_{2_r}^{maize} \times log\left(P_{rt}^{maize}\right) + \sum_l (\varepsilon_{2_{lr}}^{swine} \times log\ (P_{lrt}^{swine})) \quad (2)$$

In equations (1) and (2), A and Y are respectively the planted area and the yield of maize in each production region r∈{Haiti, Dominican Republic} in each year that is modeled t∈{2019,…, 2030}. P^{maize} is the producer price of maize, and P^{swine} is the producer price of each livestock sector l ∈{traditional pig, commercial pig} at any given year. The intercept of maize area function is notated α. The maize planted area equation (1) also consists of ε_1^{maize}, the elasticity of maize area to maize prices and ε_1^{swine}, the elasticity of maize area to prices for each type of livestock in each region and any given year. The maize yield intercept (γ) is explained further in equation 4. The elasticity of maize yield with respect to maize prices (ε_2^{maize}), and the elasticity of maize yield to price of each type of livestock (ε_2^{swine}) are included in the maize yield equation. Elasticities are held constant across time (t).

The area and yield equations are combined to define the maize supply available at any given year. Maize makes up a key portion of swine feeds in Haiti for both traditional and commercial pig production. A change in maize production and price will affect the pork industry and vice-versa. The maize supply equation establishes the relationship between the quantity of maize produced and changes in the production factors and demand by the swine sectors.

$$\alpha_{rt} = log\left(A_{0_r}\right) - \varepsilon_{1_r}^{maize} \times log\ (P_{0_{rt}}^{maize}) - \sum_l(\varepsilon_{1_{lr}}^{swine} \times log\ (P_{0_{lrt}}^{swine})) \quad (3)$$

$$\gamma_{R,T} = log\left(Y_{0_r}\right) - \varepsilon_{2_r}^{maize} \times log\left(P_{0_{rt}}^{maize}\right) - \sum_l(\varepsilon_{2_{lr}}^{swine} \times log\left(P_{0_{lrt}}^{swine}\right)) \quad (4)$$

Equation 3 formulates the intercept of maize area (α) function for each region. It includes A_0, which is the original (2019) maize area in hectare for consumption in each region, ε_1^{maize} and ε_1^{swine}, which are defined in equation 1. Included in both equations 3 and 4, P_0^{maize} is the baseline producer price of maize, and P_0^{swine} is the baseline producer price of each livestock sector (l) in Dominican Pesos. The maize yield intercept (γ), on the other hand, encompasses the 2019 maize yield in tonne per hectare (Y_0) for each region, ε_2^{maize}, and ε_1^{swine}, also defined in equation 2.

2. Livestock supply functions

Livestock supply (equation 5) in the model is limited to swine production and consists of $l \in$ {traditional pigs, commercial pigs}. Traditional pig production makes up the majority of swine farms and live pig inventory in both Haiti and the Dominican Republic (*r*). In both swine sectors the main feed grain is maize, primarily produced domestically.

$$log(S_{lrt}) = \delta_{lrt} + \sum_l(\varepsilon_{3_{lr}}^{swine} \times log\ (P_{lrt}^{swine})) + (\varepsilon_{3_{lr}}^{maize} \times log\left(P_{rt}^{maize}\right) \quad (5)$$

$$\delta_{lrt} = log\left(S_{0_{lr}}\right) - \sum_l(\varepsilon_{3_{lr}}^{swine} \times log(P_{0_{lrt}}^{swine})) - \varepsilon_{3_{lr}}^{maize} \times log\left(P_{0_{rt}}^{maize}\right) \quad (6)$$

The livestock supply equation follows a very similar procedure to the maize supply equation. It includes a double-log intercept of livestock supply (δ) stated in equation 6. The intercept of livestock supply (δ) is a function of S_0; the 2019 traditional and commercial pigs (l)

produced in each region (r); the elasticity of livestock supply with respect to own and cross swine output prices, ε_3^{swine}; and the elasticity of livestock supply to the price of maize, ε_3^{maize}. $P_0^{maize}$is the baseline producer price of maize, and P_0^{swine} is the baseline swine producer price in each region.

In equation (5), S is the supply of livestock at any given time. Equation 5 is made up of the intercept and elasticities ($\delta, \varepsilon_3^{swine}$, ε_3^{maize}). P^{maize} is the producer price of maize, and P^{swine} is the producer price of livestock.

3. Food demand functions

$$log(D_{frt}) = \vartheta_{frt} + \sum_f \left(\varepsilon_{fr}^{food} \times log\left(Z_{frt}\right)\right) + \varepsilon_{fr}^{income} \times log(I_{rt}) + log(H_{rt}) \quad (7)$$

$$\vartheta_{frt} = log\left(D_{0_{fr}}\right) - \sum_f \left(\varepsilon_{fr}^{food} \times log\left(Z_{0_{frt}}\right)\right) - \varepsilon_{fr}^{income} \times log(I_{rt}) - log(H_{rt}) \quad (8)$$

Both pork and maize are largely used for human consumption in Haiti and the Dominican Republic. The double-log food demand equation (7) defines the potential impacts of maize price, livestock price, and consumer income alterations on the quantity of food consumed f ∈{food maize, traditional pork, commercial pork}. The food demand function (D) consists of ε^{food}, the elasticity of food demand with respect to own and cross food prices, ε^{income}, the elasticity of food demand to consumer income in each region (r) and Z, the consumer price of maize and swine products at any given time (t). H, which is the total human population at time (t), adjusts food demand changes as a result of year-to-year fluctuations in population. ϑ, formulated in (8) is also included.

The intercept of food demand function (ϑ) is dependent of D_0, the 2019 food demand in Haiti and the Dominican Republic (r), the previously described elasticities ε^{food} and ε^{income}, as well as Z_0, the baseline consumer price of maize and swine products. Included in both (7) and (8), I is the income per capita in time (t) for Haiti and the Dominican Republic.

4. Feed demand functions

$$log(K_{crt}) = \varphi_{crt} + log(\sum_l(S_{lrt})) + \varepsilon_{4_{cr}}^{maize} \times log(Z_{crt}^{maize})$$

$$+ \sum_l(\varepsilon_{4_{lr}}^{swine} \times log(P_{lrt}^{swine})) \qquad (9)$$

Maize domestically produced in Haiti and the Dominican Republic is often used to feed traditional and commercial pigs, $c \in$\{feed maize\}. In equation (9), K, which is the maize demand for swine feeding purpose at a given year (t) is a function of livestock supply S, defined in equation (5). ε_4^{maize} is the maize demand elasticity with respect to maize consumer price (Z^{maize}) at time t, and ε_4^{swine} is the elasticity of maize demand to traditional and commercial pig producer prices (P^{swine}). φ, the intercept of maize demand is also included.

$$\varphi_{crt} = log(K_{0_{cr}}) - log(\sum_l(S_{0_{lr}})) - \varepsilon_{4_{cr}}^{maize} \times log(Z_{0_{crt}}^{maize})$$

$$-\sum_l(\varepsilon_{4_{lr}}^{swine} \times log(P_{0_{lrt}}^{swine})) \qquad (10)$$

Equation (10) formulates the intercept of maize demand (φ) for each pig sector of each region in the model. It consists of the coefficient ε_4^{maize}, elasticity of maize demand with respect to own baseline consumer price (Z_0^{maize}), and ε_4^{swine}, the elasticity of maize demand to producer prices (P_0^{swine}) of each livestock sector. S_0 is the 2019 livestock supply and K_0, the 2019 feed demand by both livestock sectors.

5. Balance Equations

HPM-2021 has no objective function included (Rutherford, 1995). A set of inequalities are formulated to exploit the complementarity links between various equations. The model includes a product inflow equation that ensures, under regular market conditions (no disease shocks), that domestic supply and imports of feed and food meet or surpass local demand (11). Outflow inequalities are also constructed to formulate that all produced maize (j)—consisting of both previously described feed maize (c) and food maize — and livestock supply is equal or greater than local demand and export as shown in equation (12).

$$\sum_{rr}(Q_{jlrrt} + M_{jlrrt}) \geq D_{flrt} + N_{jr} \times K_{crt} \tag{11}$$

Equation (11) is the inflow inequality where, Q is the transport of goods from one region to another rr ∈{Haiti-Dominican Republic-rest of the Caribbean-rest of the world}. M is the import of swine products and maize in tonnes from the rest of the Caribbean and the rest of the world. D and K, also included, are respectively defined in equation (7) and equation (9). N is the identity matrix for proper dimension of total feed maize and food maize demand in inflow.

$$\sum_{rr}(Q_{jlrrt} + X_{jlrrt}) \leq \sum_{l}(O_{lr} \times S_{lrt}) + \sum_{j}(N_{jr} \times V_{jrt}) \tag{12}$$

Equation 12 is the outflow inequality which consists of X, is the total maize and swine products (l) exported at time t from Haiti and the Dominican Republic to the rest of the Caribbean and the rest of the world (rr), and O, the identity matrix for proper dimension of livestock supply in outflow. S is the supply of livestock and V is the total supply of both feed and food maize at time t.

6. Incorporating Shocks

For scenario-building purposes, the intercepts of crop area (α), livestock supply (δ) and crop and livestock demand (ϑ) functions are transformed to emphasize the impacts of ASF shocks. HPM-2021 examines an ASF outbreak only in Haiti. G is the ASF-induced supply shock at time $t_1 \in (2021,\ldots,2024)$ which are the ASF outbreak years in the model. G is implemented in crop area intercept, α, to simulate indirect shocks of ASF to total maize supply (*J*) in Haiti (equation 13). *J* includes maize used for both animal consumption and human consumption.

$$\alpha_{jt_1}^{shock} = A\alpha_{jt} + log(1 - G_{jt_1}) \tag{13}$$

G incorporates ASF-induced supply shocks to livestock sectors at time t_1 by adjusting the intercept of livestock supply in Haiti (equation 14).

$$\delta_{lt_1}^{shock} = \delta_{lt} + log(1 - G_{lt_1}) \tag{14}$$

B, on the other hand, is the imposed demand shock at time t_1 to both maize and livestock sectors (l) in Haiti (equation 15).

$$\vartheta_{jlt_1}^{shock} = \vartheta_{jlt} + log\left(1 - B_{jlt_1}\right) \tag{15}$$

Finally, the model resets supply shocks for each scenario draw to restrain shocks building upon each other.

7. Estimating Producer income and Consumer Expenditure

For each of the ASF demand and supply shocks, the model estimates the impacts on pork and maize prices, pork producer income, and pork consumer expenditure. Changes in price are influenced by the baseline growth factors described in table 2, and reduced supply in demand from ASF. Revenues are calculated from the shock-induced prices and production levels. Maize and transportation costs are subtracted from those revenues to quantify fluctuations in producer gains generated by ASF. Consumer spending calculations derive from the new pork consumption levels and prices under different ASF scenarios that are defined in table 3.

Data

The model is populated by parameters on supply and demand relationships. Income, population, nominal exchange rate, technology, and international price growth also influence variations in the model. HPM-2021 development and analysis are based on secondary data collections from numerous sources. The study uses 2019 swine and maize production oriented to rural and urban consumers collected by the FAO, through its statistical database (FAOSTAT, 2019). The full set of tables containing model parameters and data sources are in the appendices.

Per capita food consumption is estimated based on production, trade, and commodity conversion ratios from producer weight to consumer weight gathered from FAOSTAT. Dominican producer prices (in DR Pesos) were forecasted from 2015 estimates using FAO’s yearly inflation index. Prices (at any level) are not regularly collected for Haiti but are available for the Dominican Republic. The 1983 USDA “Interim Swine Repopulation” is a rare report that contains 1978-1982 Haitian swine prices. Owing to limited data availability, Haitian commodity prices are an average of the USDA 1982 prices, adjusted for inflation and the accounted historical gap with Dominican prices. International trade prices are collected from the USDA and Haitian Customs office (USDA, 2014). Finally, data about socioeconomic factors that may influence market changes such as 2019 income, population growth, and nominal exchange rate derive from the World Bank database (World Bank, 2019). The collected data served in further parameters’ estimation, such as internal and external marketing margins, processing costs, and producer prices. Fluctuations in consumer income and output prices affect the quantity demanded and supplied in the different sectors.

Market responses to demand and supply relationships are structured through pre-calculated elasticities that quantify impact estimates over time. The systemic responses to changes, in the model, are driven by demand and supply elasticities. There is not a set of elasticities readily available for Haiti. Further, limitations in data and extreme events affecting the Haitian economy create challenges in the elasticity estimation process.

As a result, elasticities are calculated through numerous steps. First, year-to-year crop and livestock responsiveness are obtained based on 1990-2015 swine and maize market data (FAOSTAT, 1990-2015). Second, we estimated a median value from these annual elasticities. Some of the calculated median elasticities were particularly large positive and negative numbers, indicating anomalies the economic relationships that may derive from external factors not included in the model. To limit the potential anomalies, we constrained those 1990-2015 year-to-year elasticities to a maximum and a minimum value (Luchansky et. al., 2009). A sign constraint was also imposed to maintain proper economic relationships among commodities. After imposing those constraints, we generated stochastic elasticities for 100 iterations, with a standard deviation of 0.18 for Haiti and 0.19 for Dominican simulations, using the Simetar simulation modeling tool (Richardson, 2010). Sensitivity analysis for model parameters, including key elasticities, is found in appendices A.14 and A.15.

Scenarios

Recovery and repopulation initiatives are simulated, from 2025 to 2030, through two specific scenarios: a slow and rapid recovery scenario. The process of shaping those scenarios is detailed in the following sections.

1. Baseline Parameterization

The described model consists of a baseline that projects 2019-2020 trends, driven by changes in population, income, nominal exchange rate, and technology growth through 2030. These elements influence variations in supply and demand, and act on market prices. The baseline reflects a yearly 2.48% and 2% population and nominal exchange rate increase, respectively. A 0.5% technology growth rate is attributed to the maize sector. The traditional and commercial pig sectors do not comprise any technology growth. The rise in maize production will prospectively influence own prices and pig producers demand for feeds. Forward projections in the baseline are also guided by a yearly per capita income reduction of 3.05% assumption (Table 2). Pre-calculated elasticities are unchanged while variations in the parameters are expected to shift traditional pig, commercial pig, and maize production and consumption.

Table 2. Factor Growth Assumptions from The Baseline

Parameters	Baseline
Per Capita Income Growth	-3.05%
Population Growth	2.48%
Nominal Exchange Rate Growth	2%
Maize Technology Growth	0.50%
Traditional Pig Technology Growth	0%
Commercial Pig Technology Growth	0%
Maize World Price Growth	2.08%
Traditional Pig World Price Growth	-1.32%
Commercial Pig world Price Growth	-1.32%
Income Elasticity Multiplier for Maize	1
Income Elasticity Multiplier for T. Pig	1
Income Elasticity Multiplier for C. Pig	1
Crop Supply at Time T	1
Livestock Supply at Time T	1
Feed Demand at Time T	1
Food Demand at Time T	1
Import at Time T	1

(FAOSTAT, World Bank, USAID Data)

2. ASF Scenarios

The baseline is compared to several ASF-induced linear reductions in pig supply and demand. Production and consumption shocks are imposed from 2021 to 2024 to reflect ASF outbreak losses. The model includes five alternative scenarios: an average 3% demand-only shock, a stochastic supply-only shock, and three combinations of supply and demand shocks to traditional and commercial pig as described in table 3.

Table 3. Shock Description for ASF Prospective Impacts

Scenario Name	Description of the Scenario	Supply Shock: ASF	Demand Shock: ASF	Supply Shock: Recovery*	Demand Shock: Recovery*
Demand-0s	Average consumer Avoidance from a single farm outbreak	No	3%	Unrestricted	Unrestricted
Supply-0d	Stochastic supply shocks (100 draws only)	Mean: 15% S.D: 0.03	No	Unrestricted	Unrestricted
Supply_1d	Combined stochastic supply shocks with 1% demand shock	Mean: 15% S.D: 0.03	1%	Unrestricted	Unrestricted
Supply_3d	Combined stochastic supply shocks with 3% demand shock	Mean: 15% S.D: 0.03	3%	Restricted	Restricted
Supply_6d	Combined stochastic supply shocks with 6% demand shock	Mean: 15% S.D: 0.03	6%	Unrestricted	Unrestricted

*For additional information about the restricted and unrestricted shocks, see Table 4.

The ASF supply shock selection assumes an ASF outbreak similar in size to the previous 1980's infection. Previous ASF outbreaks have posed adverse impacts on Haitian pork supply. The historical data indicate that the supply of live pigs in Haiti dropped by an average of 15% every year from 1981 to 1984 (FAOSTAT, 2021). The 100 iterations of stochastic supply shocks are distributed around an average value of 15% and standard deviation of 0.03.

ASF does not pose a threat to human health. However, the presence of ASF has caused gratuitous concerns about disease transmission to humans, resulting in demand shocks in other countries. The potential for consumer avoidance is considered. The stochastic ASF supply shocks are combined with a small, an average, and a high demand reduction of 1%, 3%, and 6%, respectively, to illustrate aggregate ASF effects on the swine industry (table 3). Given the limited availability of pork consumption data in Haiti and the Dominican Republic, we calculated the pork demand variations using data from three other developing countries previously impacted by ASF: Ethiopia, Nigeria, and Philippines. Across the selected countries, yearly pork consumption declined by 3% on average after the first outbreaks (OECD, 2021). The highest decrease in average pork consumption (6%) was noted in Ethiopia following the 2011 ASF detection while Nigerian pork demand was the lowest drop, 1% on average.

The timeliness of ASF recovery often varies with the eradication strategy, reinfection risk, restocking costs, and new breeds' efficient integration. The latter particularly impeded Haiti's swine repopulation process after 1984's eradication. We developed two recovery possibilities to assess the prospective impacts of repopulation measures on the swine industry redevelopment. The recovery scopes complement the combined supply and 3% demand shock from 2025 to 2030 to reflect post-eradication production and consumption trends (table 3).

The first of the two recovery scenarios examined what would happen if the market was allowed to freely determine the speed of recovery without barriers. The unrestricted recovery allows the model to repopulate swine production towards baseline trends in 2025 with no barriers. This scenario would necessitate immediate funding accessibility, successful breeds' adaptation to local conditions, and biosecurity measures that prevent ASF reintroduction. Alternatively, the restricted recovery scenario reflects PEPPADEP's repopulation outcome following 1984's ASF eradication. This scenario includes setbacks and lingering shocks to domestic pig production until 2030. The following table 4 details the shock reduction extent under each recovery scenario.

Table 4. ASF Recovery Scenarios

Shocks/Year	Unrestricted	Restricted
2025	1	0.93
2026	1	0.94
2027	1	0.94
2028	1	0.95
2029	1	0.95
2030	1	0.95

Each shock specifies how much pig supply differ from baseline value

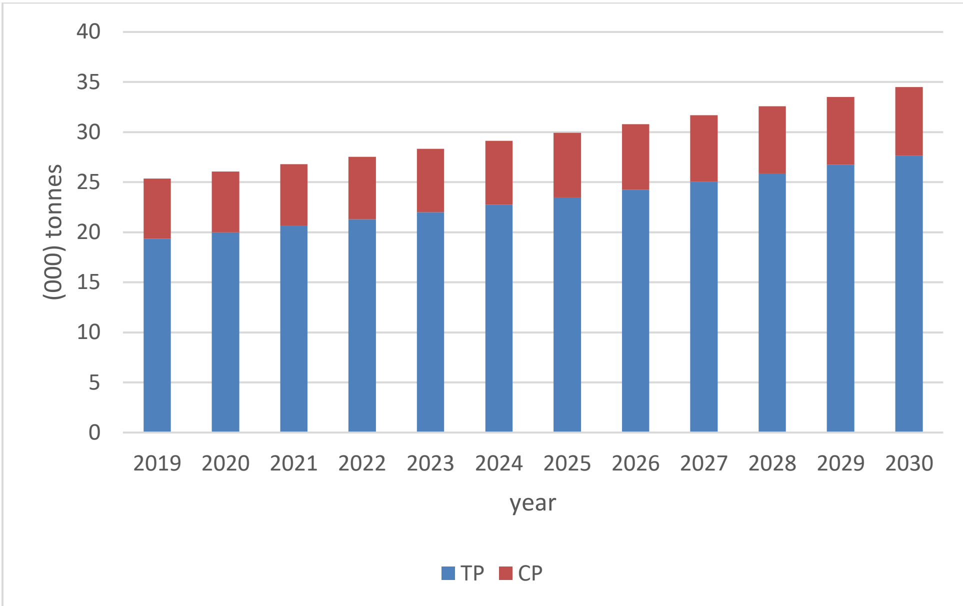
CHAPTER IV

FINDINGS AND DISCUSSIONS

Baseline Results

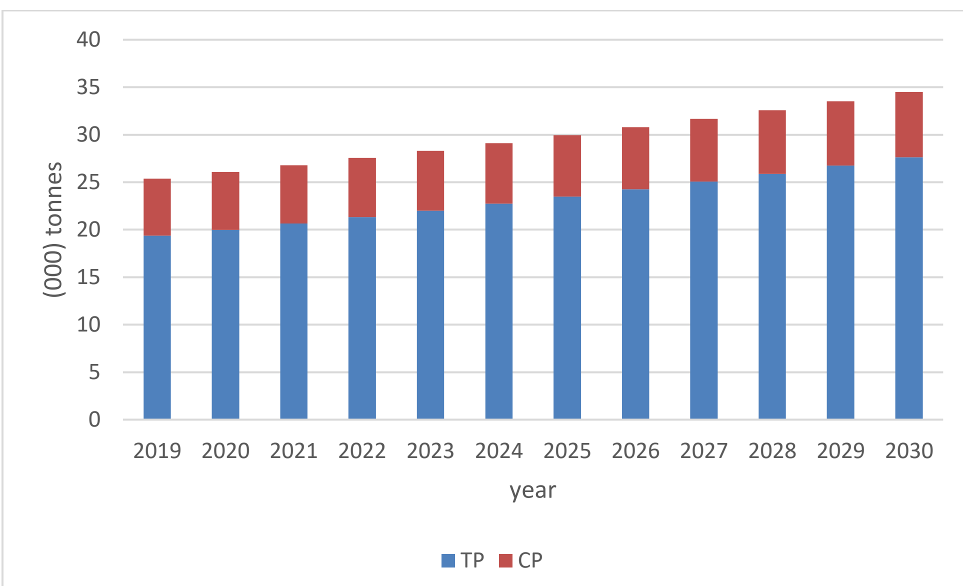
HPM-2021 simulation results in the baseline show an expanding swine industry. Domestic supply of traditional and commercial pigs is projected to increase by an average yearly rate of 3.5% (Figure 2). This is driven by an increased food demand originated by a sharp rise in the Haitian population. Despite shrinking rural population share, due to chronic out-migration, traditional pig production still dominates up to 95% of all domestic swine inventories. Demand for pork tends to grow at the same rate as supply, 3.6% yearly (Figure 3). The pig sector in Haiti involves few trading activities with other countries, and most traditional and commercial pig supply is destined for local consumption. Consequently, HPM-2021 simulations always show an equilibrium in pork products demanded and supplied.

Figure 2. Haitian Pork Supply in Baseline (a)



(a) TP is acronym for Traditional Pig and CP is an Acronym for Commercial Pig

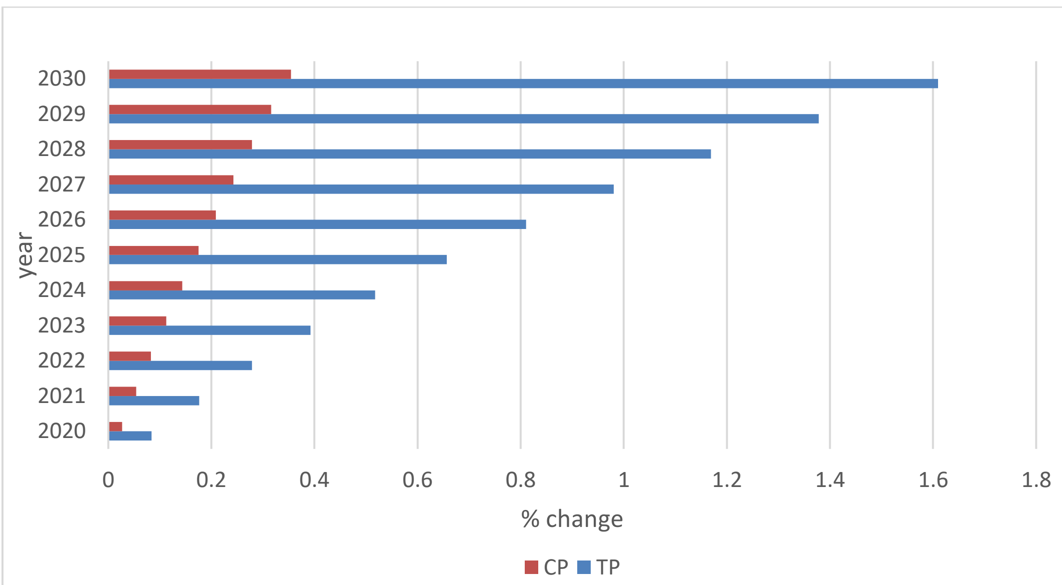
Figure 3. Haitian Pork Demand in Baseline (a)



(a) TP is acronym for Traditional Pig and CP is an Acronym for Commercial Pig

The augmentation in pork production and consumption in the baseline will prospectively lead to higher producer income, particularly in the traditional pig sector. HPM-2021 results suggest that prices will rise progressively until 2030 in both pig sectors. During the eleven-year period, commercial pig prices are forecasted to increase by an average of 4% per year (Figure 4). A faster average growth, 16% yearly, is noted in the traditional pig sector, stretching the sectoral price gap. By 2030, traditional pig price inflation will be 23 times higher than commercial pigs.

Figure 4. Traditional and Commercial Pig Price Changes in Baseline



In the initial years, higher prices may be an excellent opportunity for smallholder producers to collect additional revenues; nevertheless, the inflation will simultaneously be associated with risks of deepening food insecurity and losses due to consumers switching to cheaper substitutes, such as chickens and goats. Long-term effects of rising prices may be harmful to rural producer livelihoods and worsen the per capita income reduction trend (3.05%)

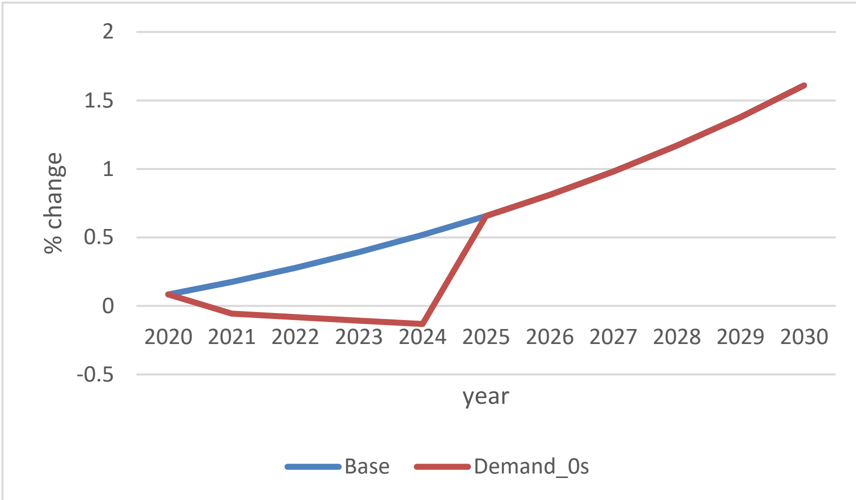
observed through 2019-2020 data. HPM-2021 does not include the cross-price demand elasticity between pork and substitutable meats that would explain consumer responses to inflation in the swine industry. This could be a subject of future research.

Demand-Only Shock

In the first alternative scenario, the baseline results are compared to a 3% (average) demand shock arising from a drop in consumer confidence due to ASF outbreaks. With the 3% demand shock imposed to traditional and commercial pigs, national supply decreases by an average of 14% for traditional pigs and 7% for the commercial pig sector between 2021 and 2024. The reduction in pork consumer spending triggers a substantial price decrease in both pig sectors (Figure 5 and 6). Throughout the ASF outbreak period, traditional pig prices fall by 32% compared to a 14% decrease in the commercial sector. As examined in the baseline, a demand shock with no accounted supply disruptions from ASF, is expected to affect more significantly the traditional pork sector than the commercial pork sector.

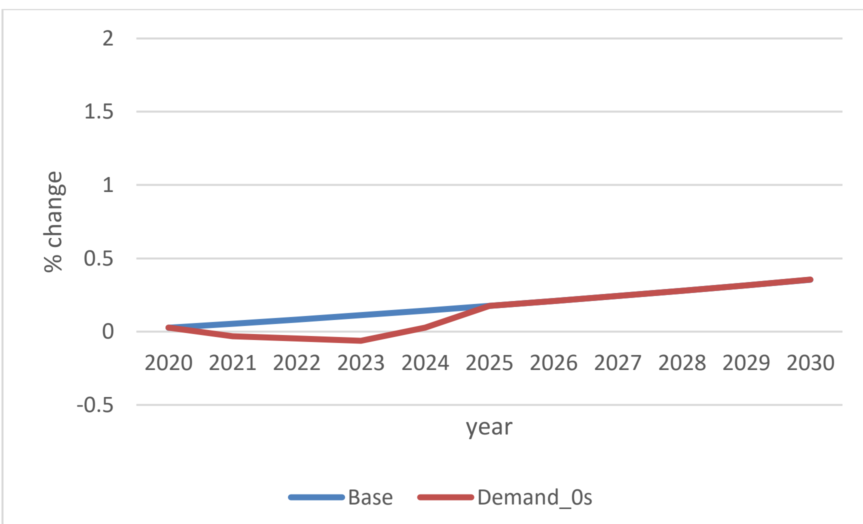
The demand shock to the pig industry, albeit relatively small, can play a sizeable role in limiting the price effects noted in the baseline. The cut in supply resulting from lower demand in both sectors leads to prices falling by nearly one-third in the traditional sector. Sharper losses in the commercial sector allow recovery to begin earlier, in 2023, despite demand shocks persisting until 2024 (Figure 6). The unrestricted recovery scenario indicates immediate price upturn from the demand shocks in 2025. The prompt recovery would highly limit the revenue losses, notably in the smallholding sector. Funding constraints and cultural adversities in Haitian swine production, however, minimize the likelihood of an immediate recovery.

Figure 5. Traditional Pig Price Changes in Demand-only Scenario (b)



(b) Shocks are described in table 3.

Figure 6. Commercial Pig Price Changes in Demand-only Scenario (b)



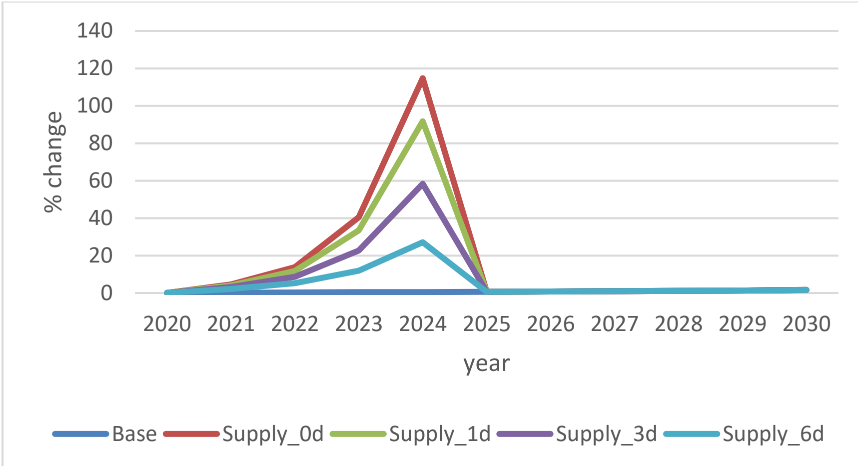
(b) Shocks are described in table 3.

Combined Supply and Demand Shocks

ASF high mortality and massive swine depopulation portend shocks to pork supply that influence economic impacts on farmers. The results show that a 15% traditional pigs supply-only reduction lifts prices by up to 118% compared to baseline levels (Figure 7). Adjustment with the three demand shocks limits the supply-induced price inflation by various magnitudes. A 1% consumer avoidance contributes to lower the supply-only shock effect by an average of 24%. The 3% average demand shock offsets the supply-related price effect by 59% during the outbreak period. Finally, when combined with a 6% demand reduction, the ASF supply impact on price decreases by an average of 90%.

The supply-driven high prices during the ASF outbreaks in the traditional pig sector have opposite implications for Haitian producers and consumers of pork products. For smallholder producers, the increased prices are an opportunity to collect further revenues. As the results suggest, this possibility tightens substantially as certain consumers tend to avoid pork. On the other hand, more expensive food negatively affects consumers spending ability. The demand-only scenario projects a decreasing trend in the per capita income. Rising prices generated by the ASF supply shocks to traditional pigs may contribute to ongoing poverty in rural communities. The disparity in price variation to shocks in the post-ASF period is associated with new pig production offtake under challenging nutritionary and veterinary conditions.

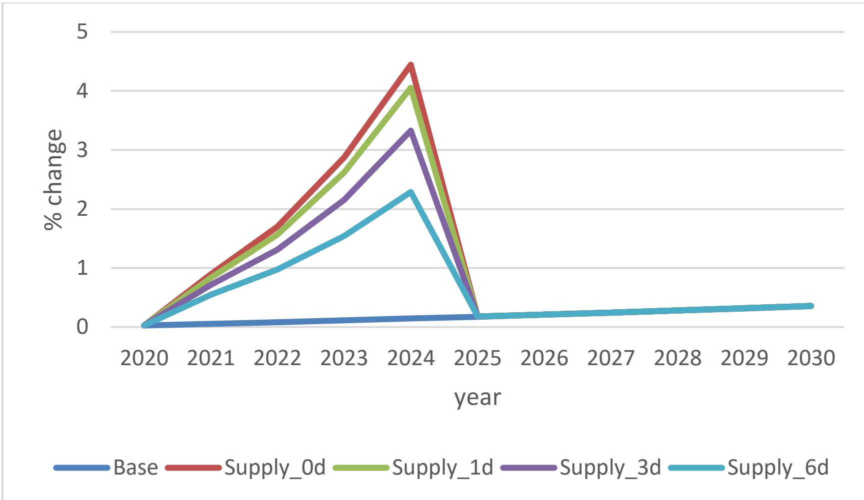
Figure 7. Traditional Pig Price Changes in Combined scenarios (b)



(b) Shocks are described in table 3

The 15% supply shock act on commercial pig prices by a dissimilar magnitude than the traditional sector. Prices ramp up by nearly 4.3% above baseline levels due to supply-only disruptions. A low consumer avoidance reduces supply effects on price by only 0.3%, whereas the average and high demand shock offsets the supply-driven increased prices by 0.9% and 1.9%, respectively (Figure 8). The findings indicate significantly lower consequences of supply disruptions in the commercial than the traditional sector. This accentuates the need for development of effective ASF control and eradication policies that preserve smallholder producer livelihoods.

Figure 8. Commercial Pig Price Changes in Combined scenarios

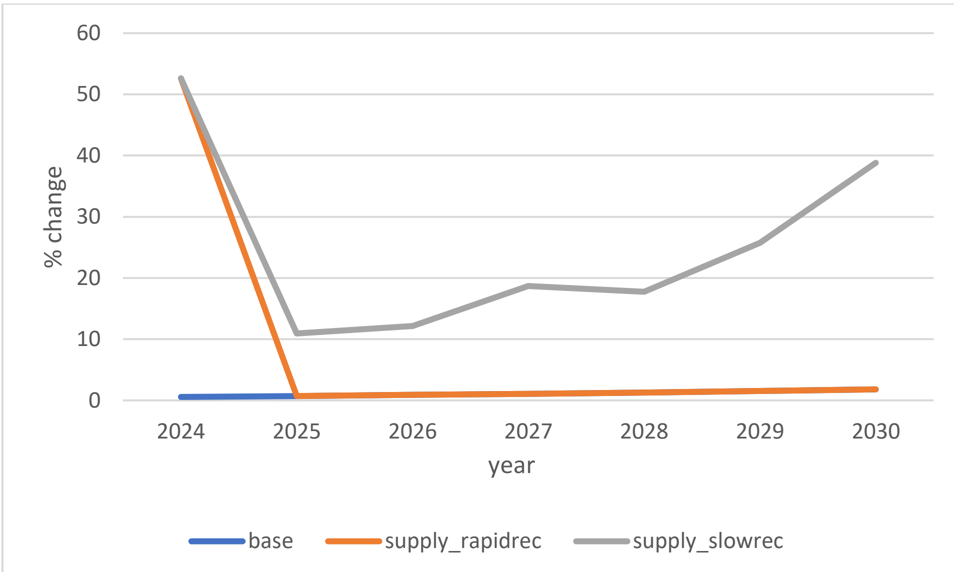


Restricted Recovery

The combined supply and 3% demand shock scenario is prolonged through 2030 to address different recovery schemes. Under an unrestricted recovery, ASF-related high prices converge almost immediately back to the baseline. The subsistence sector that constitutes most of the Haitian pig industry and with its low level of biosecurity would complicate the implementation of a strategy that more likely guarantees prompt recovery from ASF. The appropriate policies are often achievable in a more extensive modern pig sector. Unlike the traditional sector, the high levels of biosecurity and technology growth in modern pig production enhance resilience to ASF supply and demand shocks.

The restricted recovery scenario exemplifies Haiti’s previous post-ASF experience. Under this scenario, an average of 7% decrease in ASF supply shock from 2024 to 2025 contributes to lower traditional pig prices by nearly 42% (Figure 9). Despite a continued, but narrower, supply shock reduction in the following years, prices tend to move in the opposite direction. Between 2025 and 2030, supply shocks drop by an additional 2%. Simultaneously, we noted a 28% price increase.

Figure 9. Traditional Pig Price Changes in Restricted Recovery Scenario



Swine Producer Income Changes under Different ASF Scenarios

The result discussion, in the previous section, centers around the price effects of ASF supply and demand-related shocks. However, price changes do not fully capture the losses to producers whose herds were infected. HPM-2021 does not include welfare measures. The estimated producer income and consumer spending capture elements of overall sector impacts. Producers' undiversified source of income, particularly in Haitian rural communities, amplifies the degree to which smallholder livelihoods may be affected by ASF shocks. Table 5 summarizes the simulation results of ASF impacts on traditional pig producers' income. In the baseline, the constant increase in pig production and prices contributes to higher income for both the traditional and the commercial pig sector until 2030. As observed in the price results, traditional producers' average income growth by 2030 (6.01%) is more significant than commercial producers' income growth (0.81%), owing to a smaller commercial sector's share of total pork supply (table 5 and 6).

The adverse impacts of ASF on domestic pork supply generate a rapid price inflation until eradication of the disease. Lessons from previous outbreaks in Haiti have shown that many of the farmers that suffered from ASF losses received no compensation. Without a breeding stock and income source, many of those farmers fled the rural area in quest of new livelihoods. HPM-2021 simulation results indicate that in the short-term (2021-2024), the high prices generated by shortfalls in pork production are an opportunity to accelerate the income rise for the remaining farmers. It is likely this is an incentive to practice good biosecurity. However, as seen previously, high prices may have large consequences for food security and long-term livelihood sustainability.

Under the stochastic (mean:15%) supply-only shock, remaining traditional producers would see their income increase by a minimum of 49% up to a maximum of 87037% compared to the 2019 base year (Table 5). Commercial producers, on the other hand, would benefit from an income rise ranging from 2.22% to 66% in 2024 compared to the 2019 base year (table 6). The unrestricted redevelopment of the swine sectors with new imported breeds, shows a noteworthy deceleration in income change. From 2025 to 2030, the commercial pig sector continued to experience an income growth similar to the baseline under the supply with no demand shock. The traditional sector's income growth, in contrast, is lower than the baseline growth. The scope of producer gains is conditioned by the extent of the supply shocks, the possibility to import new breeds to repopulate the industry, and consumers avoidance of pork products.

Table 5. Summary Statistics of ASF Impacts on Haitian Traditional Pig Producers' Change in Income from the 2019 Base Year[1]

year	base Mean (Min, Max)	demand_0s Mean (Min, Max)	supply_0d Mean (Min, Max)	supply_1d Mean (Min, Max)	supply_3d Mean (Min, Max)	supply_6d Mean (Min, Max)
2020	0.18 (0.12,0.18)	0.17 (0.12,0.18)	0.17 (0.12,0.18)	0.17 (0.12,0.18)	0.17 (0.12,0.18)	0.17 (0.12,0.18)
2021	0.39 (0.26,0.39)	-0.12 (-0.08,-0.11)	30.41 (3.35,75.04)	25.23 (2.87,62.3)	17.23 (2.05,42.7)	9.49 (1.13,23.54)
2022	0.65 (0.42,0.65)	-0.17 (-0.12,-0.17)	233.01 (8.65,816.59)	175.94 (7.05,615.65)	99.5 (4.57,347.2)	41.4 (2.19,142.37)
2023	0.96 (0.6,0.96)	-0.22 (-0.16,-0.21)	2021.87 (20.85,9363.91)	1372.78 (16.06,6492.96)	645.96 (9.36,3122.66)	191.49 (3.85,873.69)
2024	1.34 (0.81,1.34)	-0.26 (-0.19,-0.26)	16476.26 (49.07,87037.39)	10654.17 (35.65,57920.14)	4407.96 (18.49,25150.36)	971 (6.43,5655.86)
2025	1.79 (1.04,1.79)	1.78 (1.04,1.79)	1.78 (1.04,1.79)	1.78 (1.04,1.79)	1.78 (1.04,1.79)	1.78 (1.04,1.76)
2026	2.34 (1.31,2.34)	2.33 (1.31,2.34)	2.33 (1.31,2.34)	2.33 (1.31,2.34)	2.33 (1.31,2.34)	2.33 (1.31,2.3)
2027	3.01 (1.62,3.01)	2.99 (1.62,3.01)	2.99 (1.62,3.01)	2.99 (1.62,3.01)	2.99 (1.62,3.01)	2.99 (1.62,2.97)
2028	3.82 (1.97,3.82)	3.8 (1.97,3.83)	3.8 (1.97,3.83)	3.8 (1.97,3.83)	3.8 (1.97,3.83)	3.8 (1.97,3.77)
2029	4.81 (2.38,4.81)	4.78 (2.38,4.81)	4.78 (2.38,4.81)	4.78 (2.38,4.81)	4.78 (2.38,4.81)	4.78 (2.38,4.74)
2030	6.01 (2.84,6.01)	5.98 (2.84,6.02)	5.98 (2.84,6.02)	5.98 (2.84,6.02)	5.98 (2.84,6.02)	5.98 (2.84,5.93)

[1] Each of the shock categories and characteristics are described in table 3 (chapter III)

Table 6. Summary Statistics of ASF Impacts on Haitian Commercial Pig Producers' Change in Income from the 2019 Base Year[2]

year	base	demand_0s	supply_0d	supply_1d	supply_3d	supply_6d
	Mean (Min, Max)	Mean (Min, Max)	Mean (Min, Max)	Mean (Min, Max)	Mean (Min, Max)	Mean (Min, Max)
2020	0.05 (0.04,0.05)	0.05 (0.04,0.05)	0.05 (0.04,0.05)	0.05 (0.04,0.05)	0.05 (0.04,0.05)	0.05 (0.04,0.05)
2021	0.11 (0.08,0.11)	-0.07 (-0.06,-0.07)	2.68 (0.57,4.38)	2.44 (0.49,4.02)	1.99 (0.36,3.37)	1.43 (0.17,2.48)
2022	0.17 (0.12,0.17)	-0.10 (-0.08,-0.11)	6.58 (0.99, 12.38)	5.83 (0.85,11.03)	4.52 (0.60,8.70)	2.99 (0.28,5.86)
2023	0.24 (0.17,0.23)	-0.14 (-0.11,-0.14)	14.96 (1.52,31.21)	12.88 (1.29,27.31)	9.47 (0.89,20.99)	5.73 (0.40,12.80)
2024	0.30 (0.21,0.30)	-0.16 (-0.14,-0.17)	31.15 (2.22,66.20)	26.54 (1.86,59.51)	19.09 (1.23,46.71)	10.33 (0.53,26.01)
2025	0.38 (0.26,0.38)	0.38 (0.26,0.38)	0.38 (0.26,0.38)	0.38 (0.26,0.38)	0.38 (0.26,0.38)	0.38 (0.26,0.38)
2026	0.46 (0.31,0.47)	0.46 (0.31,0.47)	0.46 (0.31,0.47)	0.46 (0.31,0.47)	0.46 (0.31,0.47)	0.46 (0.31,0.47)
2027	0.54 (0.37,0.53)	0.54 (0.37,0.53)	0.54 (0.37,0.53)	0.54 (0.37,0.53)	0.54 (0.37,0.53)	0.54 (0.37,0.53)
2028	0.63 (0.42,0.63	0.63 (0.42,0.63	0.63 (0.42,0.63	0.63 (0.42,0.63	0.63 (0.42,0.63	0.63 (0.42,0.63
2029	0.72 (0.48,0.72)	0.72 (0.48,0.72)	0.72 (0.48,0.72)	0.72 (0.48,0.72)	0.72 (0.48,0.72)	0.72 (0.48,0.72)
2030	0.81 (0.54,0.82)	0.81 (0.54,0.82)	0.81 (0.54,0.82)	0.81 (0.54,0.82)	0.81 (0.54,0.82)	0.81 (0.54,0.82)

[2] Each of the shock categories and characteristics are described in table 3 (chapter III)

Demand shocks resulting from consumer avoidance of pork products influence lower prices and have the opposite effect on swine producers' income to a supply-only shock. A 3% demand shock with no supply disruptions would cause up to 0.26% of income losses to the traditional pig producers and 0.17% to commercial pig producers compared to the 2019 base year (table 5 and 6). In the combined scenarios, demand shocks act on income by offsetting a portion of the supply-induced income gain. The results indicate that, in both the traditional and commercial sector, producers' income tends to substantially lessen as consumers avoid pork products. A slower income growth is observed in the long-term from both sectors, with the traditional pig sector showing a lower growth in the three combined scenarios than the baseline from 2027 to 2030.

As the swine industry recovers, the immediate slowdown of farmers' income growth serves as a warning to traditional and commercial pig producers that the opportunities for gains following ASF infection are temporary. The market adjustment following ASF eradication through larger imports volumes from other countries and persisting consumer avoidance of pork products may create conditions for lower gains than the baseline forecasts in the long run. The model simulation does not account for consumers shifting to substitutable meats which would also limit the remaining pig producers' income growth during ASF. The country could also bring in greater pork imports via food security programs to damper the price shocks to consumers.

Swine Consumer expenditure Change under Different ASF Scenarios

The demand shocks incorporated in HPM-2021 scenarios demonstrated the possibilities of pork consumers to undergo changes in behaviors following ASF detection. In many countries, pork avoidance may vary from 1% to 6% during the outbreak years, leading to substantial losses throughout the production system. In addition to changes in pork-consumption attitudes, ASF-induced pork prices fluctuations and lower availability will influence consumers' spending and well-being. Table 7 and 8 summarize pork consumers' spending trends with no disease shock until 2030 in comparison with various ASF outbreak scenarios.

Table 7 and 8 baseline results indicate a year-to-year increase in pork consumer's expenditures in both pig sectors until 2030. This growth is particularly driven by a growing Haitian population (2.48% yearly). Despite a lowering per capita income, higher expenditures are projected with the market incurring ASF supply shocks without any accounted consumer avoidance. In this scenario, traditional pork consumer expenditures rise by an average of 201% in 2024 compared to the 2019 base year (table 7). The commercial consumer expenditures, on the other hand, increase by only 3.11% in 2024 from the 2019 base year (table 8). Changes in the supply-only scenario are contrasted with the baseline changes from the same year to estimate consumers' change in well-being as a result of ASF shocks. By the last outbreak year (2024), traditional consumers losses could amount by an average of 200% from the baseline to the supply-only scenario, whereas commercial consumers would incur 2.89% percent in average losses.

Consumers' avoidance of pork products contributes to lower losses in the traditional and commercial pig sector. A 1%, 3%, and 6% demand reduction would respectively offset those losses by 26%, 60%, and 87% in the traditional sector, and by 7%, 32%, 64% in the commercial sector. The unrestrictive recovery from ASF would allow consumer expenditures to converge to baseline levels in 2025 in all scenarios. The incorporation of competitive sectors to pork in the model would alleviate expenditure losses as many consumers would shift towards other meats such as goat, chicken, or beef to avoid the high pork prices generated by the ASF outbreaks.

Table 7. Summary Statistics of ASF Impacts on Haitian Traditional Pig Consumers' Change in expenditures from the 2019 Base Year[3]

Year	base Mean (Min, Max)	demand_0s Mean (Min, Max)	supply_0d Mean (Min, Max)	supply_1d Mean (Min, Max)	supply_3d Mean (Min, Max)	supply_6d Mean (Min, Max)
2020	0.12 (0.12,0.12)	0.12 (0.12,0.12)	0.12 (0.12,0.12)	0.12 (0.12,0.12)	0.12 (0.12,0.12)	0.12 (0.12,0.12)
2021	0.25 (0.25,0.25)	-0.08 (-0.08,-0.08)	5.78 (3.17,10.42)	5.02 (2.72,9.11)	3.73 (1.94,6.9)	2.28 (1.06,4.43)
2022	0.41 (0.41,0.41)	-0.11 (-0.11,-0.11)	19.23 (8.17,42.83)	15.82 (6.65,35.35)	10.57 (4.32,23.89)	5.54 (2.06,12.93)
2023	0.58 (0.58,0.58)	-0.15 (-0.15,-0.15)	63.75 (19.66,174.32)	49.03 (15.15,136.56)	29.22 (8.83,83.7)	12.71 (3.62,35.73)
2024	0.78 (0.78,0.78)	-0.18 (-0.18,-0.18)	201.57 (46.21,609.65)	149.32 (33.58,465.64)	81 (17.42,267.2)	28.77 (6.06,99.62)
2025	1.01 (1.01,1.01)	1.01 (1.01,1.01)	1.01 (1.01,1.01)	1.01 (1.01,1.01)	1.01 (1.01,1.01)	1.01 (1.01,1.01)
2026	1.27 (1.27,1.27)	1.27 (1.27,1.27)	1.27 (1.27,1.27)	1.27 (1.27,1.27)	1.27 (1.27,1.27)	1.27 (1.27,1.27)
2027	1.56 (1.56,1.56)	1.56 (1.56,1.56)	1.56 (1.56,1.56)	1.56 (1.56,1.56)	1.56 (1.56,1.56)	1.56 (1.56,1.56)
2028	1.9 (1.9,1.9)	1.9 (1.9,1.9)	1.9 (1.9,1.9)	1.9 (1.9,1.9)	1.9 (1.9,1.9)	1.9 (1.9,1.9)
2029	2.29 (2.29,2.28)	2.29 (2.29,2.29)	2.29 (2.29,2.29)	2.29 (2.29,2.29)	2.29 (2.29,2.29)	2.29 (2.29,2.29)
2030	2.73 (2.73,2.72)	2.73 (2.73,2.73)	2.73 (2.73,2.73)	2.73 (2.73,2.73)	2.73 (2.73,2.73)	2.73 (2.73,2.73)

[3] Each of the shock categories and characteristics are described in table 3 (chapter III)

Table 8. Summary Statistics of ASF Impacts on Haitian Commercial Pig Consumers' Change in expenditures from the 2019 Base Year[4]

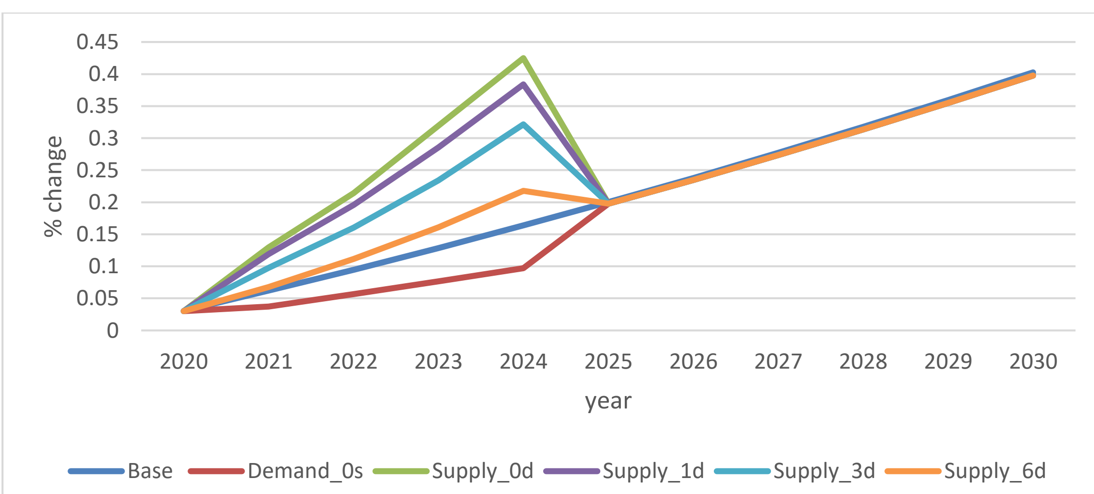
Year	base Mean (Min, Max)	demand_0s Mean (Min, Max)	supply_0d Mean (Min, Max)	supply_1d Mean (Min, Max)	supply_3d Mean (Min, Max)	supply_6d Mean (Min, Max)
2020	0.04 (0.04,0.04)	0.04 (0.04,0.04)	0.04 (0.04,0.04)	0.04 (0.04,0.04)	0.04 (0.04,0.04)	0.04 (0.04,0.04)
2021	0.08 (0.08,0.08)	-0.05 (-0.05,-0.05)	0.71 (0.51,0.99)	0.64 (0.44,0.9)	0.49 (0.32,0.73)	0.3 (0.15,0.73)
2022	0.12 (0.12,0.12)	-0.07 (-0.07,-0.07)	1.3 (0.89,1.9)	1.14 (0.76,1.7)	0.86 (0.53,1.34)	0.5 (0.24,1.34)
2023	0.17 (0.17,0.17)	-0.09 (-0.09,-0.09)	2.11 (1.37,3.16)	1.83 (1.16,2.82)	1.34 (0.79,2.19)	0.75 (0.34,2.19)
2024	0.22 (0.22,0.21)	-0.11 (-0.11,-0.11)	3.11 (1.99,4.34)	2.69 (1.66,3.99)	1.96 (1.1,3.28)	1.04 (0.46,3.28)
2025	0.26 (0.27,0.26)	0.27 (0.27,0.27)	0.27 (0.27,0.27)	0.27 (0.27,0.27)	0.27 (0.27,0.27)	0.27 (0.27,0.27)
2026	0.32 (0.32,0.32)	0.32 (0.32,0.32)	0.32 (0.32,0.32)	0.32 (0.32,0.32)	0.32 (0.32,0.32)	0.32 (0.32,0.32)
2027	0.37 (0.37,0.37)	0.37 (0.37,0.37)	0.37 (0.37,0.37)	0.37 (0.37,0.37)	0.37 (0.37,0.37)	0.37 (0.37,0.37)
2028	0.43 (0.43,0.43)	0.43 (0.43,0.43)	0.43 (0.43,0.43)	0.43 (0.43,0.43)	0.43 (0.43,0.43)	0.43 (0.43,0.43)
2029	0.49 (0.49,0.48)	0.49 (0.49,0.49)	0.49 (0.49,0.49)	0.49 (0.49,0.49)	0.49 (0.49,0.49)	0.49 (0.49,0.49)
2030	0.55 (0.55,0.55)	0.55 (0.55,0.55)	0.55 (0.55,0.55)	0.55 (0.55,0.55)	0.55 (0.55,0.55)	0.55 (0.55,0.55)

[4] Each of the shock categories and characteristics are described in table 3 (chapter III)

Indirect Consequences on Maize

Haiti's ASF outbreak can significantly generate consequences to the maize sector. Maize contributes to both household and swine nutrition. The model results highlight the sensitivity of maize prices to traditional and commercial pig shocks. The negative impacts of ASF on pig supply influence a 0.27% increase in maize price (Figure 10). As shown earlier, the demand shocks play a major role in limiting supply consequences. In the maize sector, a 3% reduction in pork consumption lowers the supply effects on prices by nearly 40%. A 6% demand shock offsets the pig supply effect on maize price by 81%. The maize price inflation will affect maize production and restrict farmer profitability. From the standpoint of households, increased food prices will accelerate food insecurity, given maize historical role in the nutritional intake of rural families. The indirect impacts of ASF on maize highlight the multifaceted economic risks of animal disease outbreaks, laying out the need for in-depth multisectoral analysis when adopting ASF eradication strategies.

Figure 10. ASF Indirect Impacts on Maize Price in Unrestricted Scenarios



CHAPTER V

CONCLUSIONS

Pigs are one of the most plentiful animals on Haitian farms and are mostly owned by small farmers in rural areas. With minimal hard currency in the rural communities, small-scale pig production serves as a source of wealth accumulation as well as a source of protein. Revenues from the sale of pigs comprise 30% of rural farm income, and are often used to finance children education, weddings, funerals, and day-to-day activities. Being a high protein food and low risk investment, pigs play a role in diminishing food insecurity and social inequality in Haitian localities. The 2021 re-introduction of ASF is a major threat to the swine sector inventory still struggling to recover from the 1985 eradication. As evidenced by the past outbreaks, the undiversified income of traditional pig producers raises the risk of impoverishment from ASF high mortality and control measures.

HPM-2021 consists of a baseline (no-ASF) which indicates an expanding pig industry. Both pork producer income and consumer expenditure show a rising trend while the sector remains very self-sufficient, with minimal trade involved. The first alternative scenario examined an ASF outbreak that is very small, such that no true change in production is experienced, but in which consumers avoid pork products. In this demand-only scenario, results suggest large income losses for traditional pig producers, driven by lower prices due to consumer avoidance of swine products. The smaller commercial sector experiences a lower scale of losses.

On the other hand, the 2021 ASF outbreak imposes adverse impacts on pork supply and consumer pork expenditures. With similar supply shocks implemented to both traditional and commercial pigs, results indicate disproportionately higher price consequences to the traditional pig sector. From the remaining pig producers' standpoint, the inflated prices show a possibility to earn additional incomes in the short-term. However, as ASF is eradicated and the recovery process launched, the supply shock reduction associated with persisting consumers' avoidance may contribute to a loss in long-term well-being. Consumers, on the other hand, will undergo increased pork expenditures during the ASF outbreak period, resulting in lower well-being until 2030. The lack of a welfare measure for impacted swine owners is a limitation of this analysis and the subject of future research.

The high prices could hinder development initiatives in the mostly poor rural communities and accentuate the lack of access to food, health, education, and other essential services. The unrestricted repopulation strategy results in rapid recovery of swine inventories. Alternatively, when repopulation is restricted to reflect historic barriers faced during the 1984 PEPPADEP recovery, longer term losses occur as a result of ASF in 2021. The results imply many socioeconomic consequences could occur. The prospective impacts on education attainment, food security, and migration outline the need to develop effective pro-poor ASF eradication and repopulation strategies.

The inflated prices are a temporary windfall for remaining pig producers able to take advantage of fewer competitors during the outbreak period. Although partially offset by consumer avoidance of pork, high prices leading to higher incomes for non-infected farms may incentivize traditional pig producers to hide ASF-likely symptoms on farm. Past studies have indicated that high market prices and high compensation can create perverse incentives for reporting (Thompson, 2002). The willingness to report disease will vary with government responses and efficient livestock valuation to determine compensation rates (Tonsor et. al., 2020).

On the other hand, hiding disease may trigger a loss of consumer confidence which can almost equally counteract the supply effects on price. Besides the overall impacts on production, the high prices of pork products may stimulate consumers' shift to cheaper imports or alternatives protein sources. This was not estimated by HPM-2021 and is subject for future research.

There are no recent assessments of ASF implications in the Caribbean, and few models that evaluate economic impacts of health response policies in less developed countries like Haiti. The lack of price data is one of the constant challenges to economic impact analysis in Haiti. Commodity prices are not regularly collected. As a result, HPM-2021 uses a combination of historical price gap with the Dominican Republic and inflation adjustments to estimate year-to-year Haitian Prices until 2019. In addition to price, no set of elasticities is readily available for Haiti. HPM-2021 elasticities are calculated based on previous years data as described in Chapter III.

This study offers a starting point for additional work on animal health response in the Caribbean. A more developed assessment of ASF economic impacts will include welfare measurements from supply and demand relationships. The welfare analysis will capture the changes on swine and maize markets' producer and consumer surpluses, as well as the multimarket "domino" effects that may be originated from distortions in the swine sector. Future modelling activities may also be conducted to assess the unrestricted ASF impacts to other related sectors of Haiti's economy, such as crop inputs and substitutable meats like chicken and goat. Including additional swine feeds and competitive meats would broaden the producer costs calculation and consumer shocks due to the opportunity to shift consumption to other non-infected products. This would involve cross-sectoral data gathering and elasticity calculations to influence variations in pork prices and well-being. Lastly, the analysis may include a vaccine development scenario. A vaccination scenario would require experimental data about the evolving ASF vaccine, or the historical effectiveness of vaccines in reducing the impacts of related diseases, such as Classical Swine Fever.

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APPENDICES

A.1

TABLE MPAR(J,L) Market parameters

	CONV	PMARGPR	CTA	XPRO	FEEDCONV
MAIZE	0.90	0.10	1		
TRADPIG	0.50	0.05	3		3.8
COMMPIG	0.50	0.05	3	10000	3.0

"CONV" is the conversion ratio from consumer weight to producer weight, "PMARGPR" the processing costs, "CTA" the cost of transportation for each commodity, "XPRO" the extra processing costs associated with exports, and "FEEDCONV is the feed-meat conversion ratio.

A.2

TABLE AREA0(J,R) Original crop area for urban-rural consumption 2019 (1000ha)

		URBAN	RURAL	**TOTAL**
MAIZE	HT	221.860	77.72	**299.58**
MAIZE	DR	17.209	12.058	**29.27**
MAIZE	CB	286.028	174.124	**460.15**

Source: FAOSTAT data.

A.3

TABLE YIELD0(J,R) Original crop yield for urban-rural consumers 2019 (ton per har)

		URBAN	RURAL	**TOTAL**
MAIZE	HT	0.80	0.80	**0.80**
MAIZE	DR	1.87	1.87	**1.87**
MAIZE	CB	1.40	1.40	**1.40**

Source: Ralph's estimates based on FAOSTAT data.

A.4

TABLE PROD0(J,L,R) Original production oriented for urban & rural consumer groups 2019 (1000tons)

		URBAN	RURAL	**TOTAL**
MAIZE	HT	177.488	62.179	**220**
MAIZE	DR	32.181	22.548	**49.840**
MAIZE	CB	400.439	243.774	**586.330**
TRADPIG	HT	11.970	10.441	**22.411**
TRADPIG	DR	13.202	8.382	**21.584**
TRADPIG	CB	118.791	66.754	**185.545**
COMMPIG	HT	6.580	3.024	**9.604**
COMMPIG	DR	24.763	13.609	**38.372**
COMMPIG	CB	118.791	66.754	**185.545**

Source: FAOSTAT data.

The distribution of commodity production for urban and rural consumer is proportional to the urban and rural consumption.

A.5

TABLE PD0(J,R) Original consumer price 2019 (DR Pesos per kg)

		URBAN	RURAL	**TOTAL**
MAIZE	HT	612.20	612.20	**612.20**
MAIZE	RD	498.88	498.88	**498.88**
MAIZE	CB	993.10	993.10	**993.10**
TRADPIG	HT	4870	3030	**3950.00**
TRADPIG	DR	1979	1979	**1978.88**
TRADPIG	CB	4889	4889	**4888.90**
COMMPIG	HT	4870	4030	**4450.00**
COMMPIG	DR	1979	1979	**1978.88**
COMMPIG	CB	4889	2390	**3639.45**

Source: Prices are gathered from the USAID 1983 "Interim Swine Repopulation" and FAOSTAT. 2019 Haitian Prices are calculated based on historical gap with Dominican prices, accounting inflation.

A.6

TABLE DPC0(F,R) Original per capita food cons. 2019 (kg per per year)

		URBAN	RURAL	**TOTAL**
MAIZE	HT	28.054	18.286	**23.17**
MAIZE	DR	89.978	367.950	**228.96**
MAIZE	CB	58.886	123.999	**91.44**
TRADPIG	HT	1.298	1.400	**1.35**
TRADPIG	DR	2.374	6.457	**4.42**
TRADPIG	CB	2.715	3.794	**3.25**
COMMPIG	HT	0.951	0.540	**0.75**
COMMPIG	DR	3.119	7.342	**5.23**
COMMPIG	CB	2.715	3.794	**3.25**

Source: Ralph's estimates based on FAOSTAT data. The per capita food consumption is estimated based on production, trade, and commodity conversion ratios from producers to consumers wight gathered from FAOSTAT.

A.7

TABLE YPC0(R) Urban & rural per capita income in 2019 (DR Pesos per person per yr)

	URBAN	RURAL	TOTAL
HT	702.760	568.561	642.152
DR	6708.515	1573.602	5736.692
CB	7352.340	3003.068	6105.091
	6350.834	2239.128	5126.054

TABLE YGR(R) Annual income growth 2019-2020

	URBAN	RURAL	TOTAL
HT	-0.035	-0.025	-0.0305
DR	-0.080	-0.040	-0.0783
CB	-0.080	-0.030	-0.0728

Source: WorldBank Database

A.8

TABLE POP0(R) Urban & rural population in 2019 (1000 inhabitants)

	URBAN	RURAL	**TOTAL**
HT	6143.008	4969.937	**11123.18**
DR	8823.303	2059.693	**10883**
CB	31492.82	12662.505	**44155.32**
	46459.13	**19692.135**	**66161.5**

TABLE PGR(R) Annual population growth 2019-20 (fraction)

	URBAN	RURAL	TOTAL
HT	0.0301	0.0183	0.0248
DR	0.0397	0.0456	0.0408
CB	0.0216	0.0321	0.0247

Source: FAOSTAT and WorldBank Database

A.9

TABLE AREAE(J,R) Elasticity of crop area with respect to output price

	HT	DR	CB
MAIZE	0.37	0.36	0.34

TABLE YIELDE(J,R) Elasticity of crop yield with respect to output price

	HT	DR	CB
MAIZE	0.01	0.41	0.22

Haitian Elasticities are calculated following the procedures described in Chapter III

A.10

TABLE LVELAS(L,R) Elasticity of livestock supply with respect to output prices

		HT	DR	CB
TRADPIG	TRADPIG	0.900	0.610	**0.900**
TRADPIG	COMMPIG	-0.620	-0.030	**-0.620**
COMMPIG	TRADPIG	-0.620	-0.030	**-0.620**
COMMPIG	COMMPIG	0.900	0.610	**0.900**

A.11

TABLE LVFDEL(L) Elasticity of livestock supply with respect to feed prices

	MAIZE
TRADPIG	-0.002
COMMPIG	-0.002

A.12

TABLE DYE(F,R) Food demand elasticity with respect to consumer income

		URBAN	RURAL	**TOTAL**
MAIZE	HT	0.467	-1.417	**-0.113**
TRADPIG	HT	0.986	1.336	**0.014**
COMMPIG	HT	1.095	1.470	**0.065**

A.13

TABLE DPE(F,R) Food demand elasticities with respect to food prices

			TOTAL
MAIZE	MAIZE	HT	**-0.461**
MAIZE	TRADPIG	HT	**0.058**
MAIZE	COMMPIG	HT	**0.058**
TRADPIG	MAIZE	HT	**-0.002**
TRADPIG	TRADPIG	HT	**-0.013**
TRADPIG	COMMPIG	HT	**0.339**
COMMPIG	MAIZE	HT	**-0.241**
COMMPIG	TRADPIG	HT	**0.083**
COMMPIG	COMMPIG	HT	**-0.384**

A.14

Sensitivity Analysis for Haitian Population and Income

Parameters	% Change	TP Price Change	CP Price Change	Maize Price Change
PGR	0.050	-0.008	0.005	0.004
Base Value –3.405	0.200	-0.074	-0.033	-0.027
	0.500	0.380	0.093	0.106
	1.000	0.966	0.199	0.228
YGR	0.050	0.000	0.000	0.000
Base Value 2.48	0.200	0.002	0.001	-0.001
	0.500	0.005	0.004	-0.003
	1.000	0.010	0.007	-0.005

TP is an acronym for the traditional pig sector, CP is for the commercial pig sector.

The analysis shows particularly high sensitivity to population change.

A.15

Sensitivity Analysis for Haitian Elasticities

Parameters	Change	TP Price Change	CP Price Change	Maize Price Change
AREAE	0.050	0.005	0.005	0.017
	0.200	0.019	0.020	0.062
	0.500	0.043	0.045	0.131
	1.000	0.074	0.077	0.209
YIELDE	0.050	0.000	0.000	0.001
	0.200	0.001	0.001	0.002
	0.500	0.002	0.002	0.006
	1.000	0.003	0.003	0.011
LVELAS	0.050	0.000	0.000	0.000
	0.200	0.000	0.000	0.000
	0.500	0.000	0.000	0.000
	1.000	0.000	0.000	0.000
LVFDEL	0.050	0.000	0.000	0.000
	0.200	0.001	0.000	0.001
	0.500	0.002	0.000	0.002
	1.000	0.004	0.001	0.004

DYE	0.050	0.001	0.001	0.000
	0.200	0.003	0.002	0.001
	0.500	0.008	0.005	0.002
	1.000	0.015	0.010	0.005
DPE	0.050	0.000	0.000	0.000
	0.200	0.000	0.000	0.000
	0.500	0.000	0.000	0.000
	1.000	0.000	0.000	0.000

Changes in elasticity scale show little price variation regardless of the sector.

VITA

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