Modeling the Potential Impacts of African Swine Fever on Chinese Whey Demand

Lesley Ahmed and Samantha Schreiber

ECONOMICS WORKING PAPER SERIES
Working Paper 2020–03–B

U.S. INTERNATIONAL TRADE COMMISSION
500 E Street SW
Washington, DC 20436

March 2020

Office of Economics working papers are the result of ongoing professional research of USITC Staff and are solely meant to represent the opinions and professional research of individual authors. These papers are not meant to represent in any way the views of the U.S. International Trade Commission or any of its individual Commissioners. Working papers are circulated to promote the active exchange of ideas between USITC Staff and recognized experts outside the USITC and to promote professional development of Office Staff by encouraging outside professional critique of staff research. The authors thank Justin Choe, Brad Gehrke, and David Riker for helpful comments and related research collaboration.

Modeling the Potential Impacts of African Swine Fever on Chinese Whey Demand
Lesley Ahmed and Samantha Schreiber
Office of Economics Working Paper 2020–03–B
March 2020

Abstract

China is the world's largest whey product importer with $622 million in total whey imports in 2018 alone. A third of those imports were sourced from the United States, China's leading import supplier, with a large portion used in pig feed. China is also the world's largest swine producer, but African Swine Fever (ASF) outbreaks beginning in 2018 have caused significant losses to China's swine inventories. The large reduction in the Chinese swine herd from ASF is expected to have large negative impacts on Chinese demand for U.S. whey for pig feed. In the short term, fewer pigs translates to less demand for whey used in pig feed. In the long term, whey demand could exceed previous levels if a larger share of future hog production is from large, commercial pig farms that have higher whey inclusion rates in pig rations. To investigate the effects of the diminished Chinese swine herd on whey demand, we build an industry-specific model of Chinese swine and whey and run a series of counterfactual analyses. We find significant negative impacts of ASF on trade and prices. We include scenarios with Chinese tariffs on U.S. whey and find significant trade diversion as remaining swine producers shift to other whey suppliers. We also present scenarios without additional Chinese tariffs on U.S. whey for feed use, which were removed in September 2019.

Lesley Ahmed, Office of Industries
lesley.ahmed@usitc.gov

Samantha Schreiber, Office of Economics
samantha.schreiber@usitc.gov

1 Introduction

The African Swine Fever (ASF) outbreak in China has caused a significant reduction in Chinese swine inventory with estimates ranging from 40-60% of pigs lost. China is the world's largest pork producer, housing nearly half of global swine stocks, so impacts of ASF on the Chinese swine herd have global implications. One upstream industry affected by ASF is whey products used in piglet feed, an important input to swine and pork production. China, with virtually no whey production, is the world's largest whey importer, and in 2018 a third of their whey was sourced from the United States.[1] A large portion of the imported whey is used in piglet feed as a source of protein and lactose. This paper attempts to quantify the impacts of ASF on Chinese demand for U.S. whey.

To understand the impacts of ASF on Chinese imports of U.S. whey, we build an industry-specific partial equilibrium (PE) model of both intermediate whey and final goods swine markets. Whey is linked to swine as an intermediate good used in production. Swine producers imperfectly substitute across country suppliers of whey with a constant elasticity of substitution. In addition to modeling ASF shocks, we also include the increase in Chinese tariffs on U.S. whey that occurred in 2018 and the removal of tariffs on whey permeate for pig feed that occurred in September 2019. The model estimates significant price changes, large impacts to trade, and, when tariffs are in effect, trade diversion to other whey suppliers.

In Section 2, we describe the current state of ASF in the Chinese swine market. Section 3 outlines the modeling approach used in this analysis. We describe the data sources in Section 4. In Section 5, we present estimated effects of ASF on whey demand, and we conclude in Section 6.

[1] Whey and modified whey, classified under Chinese HTS 0404.1000, includes whey permeate and other products for feed as well as some whey products for human consumption. See Section 4 for discussion of trade data adjustments.

2 Background

The African Swine Fever is a highly contagious virus with nearly a 100% mortality rate after infection. ASF can be spread through direct contact with an infected animal, though indirect contact from ingestion of contaminated materials, and through contact with farm equipment such as transport vehicles, clothing, and others. The disease has no treatment or vaccination, so the only way to stop the spread is to depopulate all infected pigs. The first case of ASF in China was reported in August 2018, but eventually spread to the other provinces by the middle of 2019 (Haley and Gale, 2020).

Estimates of Herd Reduction

It is too early to understand the full impact of ASF on the Chinese swine herd. As of October 2019, the National Bureau of Statistics in China reported a decline in swine inventory of 40% compared to the previous year. Some experts say the number is a little higher, estimating that 40-50% of pigs in China were lost from a combination of infected pigs dying, culled for preventative measures, or sent to market early when the disease is discovered nearby (Patton and Gu, 2019). Another source reported ASF affecting 150-200 million pigs, and potentially killing a quarter of the world's pig population (McCarthy, 2019). Because the percentage decrease in the pig herd is uncertain, we model a low and high estimate and report a range of results in Section 5.

Chinese Dairy Tariffs

Concurrent to the ASF outbreak, the Chinese government increased tariff rates on imports of U.S. whey. Chinese tariff rates on whey and modified whey increased by 25% on July 6th, 2018.[2] These tariff increases, along with the significant declines in the swine herd from

[2] China increased tariffs in imports of U.S. whey and modified whey classified under Chinese HTS 0404.1000 by an additional 25 percent. (Government of China, 2018)

ASF, contributed to reductions in U.S. whey exports in 2019. One source lists the decline in U.S. dairy exports to China at 47% over a 12-month period (O'Keefe, 2020). Not only is there less total demand for whey from Chinese swine producers, but current producers shifted whey sourcing to other competitor countries after tariffs on U.S. whey were increased. On September 17th, 2019 China exempted imports of U.S. whey permeate for feed use from tariffs.[3]

Industry Consolidation

Before ASF, many swine producers in China (up to 40%) were small- to medium-sized farms. After the spread of ASF, the Chinese swine industry began experiencing "industry consolidation" as small-scale pig farms closed down, giving larger commercial farms more market share (Pan, 2018). Further, several components of China's 2019 "Three-Year Plan to Speed up Recovery of Hog Production" could further that trend.[4] This is interesting for whey demand because larger commercial pig farms wean their piglets earlier, leading to more whey consumption during a pig's lifetime. According to industry experts, the whey consumption rate before ASF in China was roughly 0.45 kg/piglet weaned. This is expected to increase over time as industry consolidation occurs.[5] We model industry consolidation and present estimated effects on whey at the end of Section 5.

[3]Whey permeate for feed use is HTS 0404.1000. (Government of China, 2019)

[4]The plan, issued December 4, 2019, includes measures such as allowing construction on hog operations with 5,000 or more head to begin without final environmental approvals, subsidized purchases of modern feeding and environmental control equipment, and the creation of 120 replicable demonstration farms. (Dim Sums Blog, 2019)

[5]For comparison, the U.S. whey consumption rate is 2.2 kg/piglet weaned by some industry estimates. While the Chinese whey consumption rate is not expected to be as high as the U.S. after industry consolidation, it will likely increase to a level closer to the U.S. swine industry, which is primarily made up of large-scale commercial farms.

3 Sector-Specific Modeling Framework

We model both the intermediate goods (whey) and final goods (swine) markets with an industry-specific partial equilibrium modeling framework. The model assumes perfect competition in both whey and swine markets. Varieties of whey and swine are differentiated by source country and demand is modeled with Constant Elasticity of Substitution (CES) functional forms.[6] Pig farms imperfectly substitute across sources of whey with an elasticity of substitution θ. We do not model the pork industry explicitly; we treat pork and other meat substitutes as outside the model.

The Chinese whey market is supplied by several countries: the United States, European Union, Belarus, Argentina, and an all-other category. The Chinese swine market primarily consists of domestically produced swine, but we also model the small quantity of foreign imported swine to capture small-scale inventory re-build. Let p_d be the price of Chinese domestically-produced swine, p_f be the price of swine imports into China, p_s be the price of imports of U.S. whey, and p_e, p_b, p_a, and p_n be the price of imports of EU, Belarus, Argentina, and all-other whey, respectively.

The swine elasticity of substitution σ represents how Chinese consumers substitute across swine sources. The whey elasticity of substitution θ represents how Chinese consumers of whey, or the swine producers, substitute among whey varieties in response to a relative price change. The intermediate goods elasticity of substitution λ represents the substitutability of whey with other swine production inputs, like soybean meal.

The demand asymmetry parameters β, α, and γ capture preference asymmetries and quality differences, and are calibrated to initial market data. The Chinese tariff rate on imports of U.S. whey is t_s. All other non-whey production inputs are grouped into an

[6] The model is a variation of the classic Armington trade model found in Armington (1969). The model is a customized version of the intermediate goods model found on the Trade Policy PE Modeling Portal (Riker and Schreiber, 2020).

exogenous category, represented by exogenous price w. Following CES functional forms, equation (1) is the swine price index and equation (2) is the whey price index. The price of Chinese domestic swine, p_d, is a function of the price of intermediate inputs as in (3):

$$P = (p_d{}^{1-\sigma} + \beta \; p_f{}^{1-\sigma})^{\frac{1}{1-\sigma}} \tag{1}$$

$$z = (p_n{}^{1-\theta} + \gamma_1 \; (p_s \; (1+t_s))^{1-\theta} + \gamma_2 \; p_e^{1-\theta} + \gamma_3 \; p_b^{1-\theta} + \gamma_4 \; p_a^{1-\theta})^{\frac{1}{1-\theta}} \tag{2}$$

$$p_d = (w^{\;1-\lambda} + \alpha \; z^{\;1-\lambda})^{\frac{1}{1-\lambda}} \tag{3}$$

Equations (4) and (5) are demands for domestic and imported swine, where k is a demand parameter that is calibrated to the size of the market.

$$q_d = k \; P^{\sigma-1} \; p_d{}^{-\sigma} \tag{4}$$

$$q_f = k \; \beta \; P^{\sigma-1} \; p_f^{-\sigma} \tag{5}$$

Demand for Chinese imports of U.S. whey are represented by equation (6).

$$q_s = \Big(\frac{k \; \gamma_1 \; \alpha}{p_s(1+t_s)}\Big)\Big(\frac{p_d}{P}\Big)^{1-\sigma}\Big(\frac{z}{p_d}\Big)^{1-\lambda}\Big(\frac{p_s(1+t_s)}{z}\Big)^{1-\theta} \tag{6}$$

All other whey varieties $i \in (e, b, a, n)$ have the following demand equations, which are directly a function of the swine prices:

$$q_i = \Big(\frac{k \; \gamma_i \; \alpha}{p_i}\Big)\Big(\frac{p_d}{P}\Big)^{1-\sigma}\Big(\frac{z}{p_d}\Big)^{1-\lambda}\Big(\frac{p_i}{z}\Big)^{1-\theta} \tag{7}$$

Equation (8) is the supply function for each product, with constant price elasticity of supply

e_i and calibrated parameters a_i.

$$q_i = a_i \, p_i^{e_i} \tag{8}$$

There are four policy changes in the model. First, we model the increase in the Chinese tariff on U.S. whey. Second, we model the reduction in Chinese swine from ASF. This is practically modeled as a shock to the cost of production w, calibrated to the target swine inventory loss before any tariff effects take place in the model. Third, we model the exemption of imports of U.S. whey for pig feed from the Chinese tariff. Fourth, we model an increase in whey feed inclusion rates from modernization and consolidation of the Chinese hog sector.

Equations (1) through (8) represent the market equilibrium. The model requires initial expenditures of domestic and foreign products and initial and new tariff rates to calibrate parameters from the initial equilibrium. The data requirements are further described in Section (4). The demand and supply elasticities (σ, θ, λ, and e_i) were chosen qualitatively based on specialized industry knowledge.

4 Data Sources

This section details the data used to establish an initial equilibrium in the model before the tariff and ASF shocks. Chinese swine production data inputs were obtained from FAOSTAT. We used the 2017 pork production carcass weight, converted to live weight via a conversion factor, to get a 2017 swine production quantity measure. The pork-to-live weight conversion factor of 0.72 was obtained from the Oklahoma Department of Agriculture, Food, and Forestry. For the initial swine price, we used a 3-year average live weight unit price from FAOSTAT from 2014-2016. Initial imports of foreign swine in 2017 were obtained from IHS Markit. Initial imports of each whey variety[7] were also obtained from IHS Markit, and

[7]Whey and whey permeate under Chinese HTS 0404.1000

adjusted down to only include whey used as pig feed in the swine production process, using an estimate of the percentage of whey imports used in pig feed from U.S. industry experts. Similar deflation factors were used to adjust whey imports from other source countries.

Table 1: Baseline Data Inputs, 2017

	Values (in $ millions)	Source
Chinese swine production	142,352.6	Estimated from FAOSTAT data
Chinese imports of foreign swine	20.6	IHS Markit
Chinese imports of U.S. whey	168.3	Estimated from IHS Markit
Chinese imports of E.U. whey	158.7	Estimated from IHS Markit
Chinese imports of Belarus whey	2.6	Estimated from IHS Markit
Chinese imports of Argentina whey	9.8	Estimated from IHS Markit
Chinese imports of all-other whey	20.6	Estimated from IHS Markit

Table 2: Model Parameter Inputs

	Value
Elasticity of substitution between whey varieties	6
Elasticity of substitution between swine varieties	2
Elasticity of substitution between whey and other production inputs	0.05
U.S. price elasticity of supply	6
E.U. price elasticity of supply	4
Belarus price elasticity of supply	4
Argentina price elasticity of supply	4
Other whey imports price elasticity of supply	4
Other swine imports price elasticity of supply	1

The model requires a number of parameter inputs that describe responses to changes in prices. The parameter inputs chosen for this exercise are presented in Table 2. We used a medium to high substitution elasticity across whey varieties because it is a relatively undifferentiated product. We chose a low elasticity of substitution and price elasticity of supply for swine because nearly all imported swine are high-value breeding stock and also to capture the difficulty of foreign suppliers to fill the Chinese market. Absent additional information about supply elasticities for each of the whey sources, we assume each has the same value. The elasticity of substitution between whey and other production inputs is near zero to reflect the inability to use another production input in replace of whey when piglets are recently weaned.

Table 3 lists the policy changes and shocks used in the model. Because there is uncertainty over how many pigs were affected by ASF in China, we consider a low and high estimate.

Table 3: Policy Changes and Shocks

	Value
Chinese tariff increase on U.S. whey	2% to 27%
Low estimate of the loss in swine inventory from ASF	30%
High estimate of the loss in swine inventory from ASF	50%

5 Results

Modeling results are reported in Table 4. In the low scenario column in Table 4, we model a 30% decline in swine population and a 25% tariff increase on U.S. whey. In the high scenario, we model a 50% decline in swine population and a 25% tariff increase on U.S. whey. First examining the results for the swine market, the price of Chinese swine significantly increases, by 44.4% and 101.4% for low and high scenarios, as domestic swine inventory diminishes. This price increase is consistent with current industry estimates of swine and pork increases in China. Second, the model estimates large increases in foreign imported swine of 20.2% and 41.9% to cover some of the lost domestic herd. However, this is primarily breeding stock for herd rebuilding and nowhere near a one-for-one replacement of the lost Chinese pig inventories. Because China has the world's largest pig herd, it would not be possible for the foreign market to completely replace the Chinese pig herd lost from ASF and replacement of pork is more likely than live swine. This can be seen in the magnitude of the initial swine values reported in Table 1.

Turning to whey results, the quantity of Chinese imports of U.S. whey declined 53.1% and 67.3% for low and high scenarios. The total demand decline from ASF has a negative impact on trade from all countries, but the addition of the Chinese tariff on U.S. whey causes remaining swine producers to shift sourcing of whey to other countries because of the relative price increase. Comparing percent changes of U.S. whey to non-U.S. whey, we see that the decrease in imports of U.S. whey were bigger than the other whey sources because of the tariff imposition, as remaining Chinese swine producers switch to other whey sources.[8]

Table 4: Model Results under ASF Inventory Declines and Chinese Tariff Increases

	Low Scenario Results	High Scenario Results
Tariff Change	2% to 27%	2% to 27%
Reduction in Chinese swine herd	30%	50%
Elasticity of substitution, swine	2	2
Elasticity of substitution, whey	6	6
Price of Chinese swine	44.4%	101.4%
Producer price of U.S. whey[9]	-11.9%	-17%
Consumer price of U.S. whey[10]	9.7%	3.3%
Price of non-U.S. whey	-2.0%	-8.8%
Quantity of Chinese swine	-30.8%	-50.4%
Quantity of foreign imported swine	20.2%	41.9%
Quantity of Chinese imports of U.S. whey	-53.1%	-67.3%
Quantity of Chinese imports of non-U.S. whey	-7.7%	-30.9%

We also report low and high scenario results without the 25% tariff increase in table 5. In this set of simulations, the negative impacts on whey from the reduction in swine inventory are more evenly distributed across whey suppliers. Because there is no tariff, relative costs to swine producers are not as high, so the percent decline in Chinese swine production is not as negative as in table 4. As a result, the model estimates less foreign imported swine to fill the market in this scenario.

Next, we consider post-ASF industry consolidation as described in Section 2. Using the results from the low scenario (30% herd reduction) as a starting point, we model the increasing whey consumption rate by increasing total demand for whey used in pig feed.[11]

[8]Other whey producing countries would be capable of supplying this additional demand.

[9]This is the delivered price to the whey producers in the U.S., not the price the swine producers pay.

[10]This is the price the swine producers pay for whey originating in the U.S.

[11]The model uses a static framework so there is no time element. The model results under the industry

Table 5: Model Results with ASF Inventory Declines and No Tariff Changes

	Low Scenario Results	High Scenario Results
Tariff Change	2% to 2%	2% to 2%
Reduction in Chinese swine herd	30%	50%
Elasticity of substitution, swine	2	2
Elasticity of substitution, whey	6	6
Price of Chinese swine	42.9%	100.0%
Producer price of U.S. whey	-6.1%	-11.5%
Consumer price of U.S. whey	-6.1%	-11.5%
Price of non-U.S. whey	-7.2%	-13.6%
Quantity of Chinese swine	-30%	-50%
Quantity of foreign imported swine	12.6%	26.0%
Quantity of Chinese imports of U.S. whey	-31.3%	-51.9%
Quantity of Chinese imports of non-U.S. whey	-26.0%	-44.3%

The model calibrates the whey parameter α from equation (3) using an estimate for the percent increase in total whey demand in China. In this counterfactual, we consider three alternative scenarios. IC1 is the conservative scenario where there is no rebounding of the Chinese swine herd, the Chinese tariff increases are still in place, and total demand for whey in swine production increases by 50%. IC2 is the medium scenario where the Chinese swine herd rebounds by 30%, the Chinese tariff increases are still in place, and total demand for whey in swine production increases by 50%. IC3 is the high scenario where the Chinese swine herd rebounds 30%, the Chinese tariff on U.S. whey returns back to 2%, and total demand for whey in swine production increases by 50%. Selected modeling results are reported in Table 6.

Table 6: Industry Consolidation Modeling Results

	Table 4 Low Results	IC1	IC2	IC3
Tariff Change	2% to 27%	N/A	N/A	27% to 2%
Increase (decrease) in Chinese swine herd	-30%	0	30%	30%
Increase in total whey demand from industry consolidation	0	50%	50%	50%
Chinese imports of U.S. whey				
% change from post-ASF levels	0%	47.4%	60.0%	133.3%
% change from pre-ASF levels	-53.1%	-30.9%	-25.0%	0.1%

consolidation scenario are assumed to be long-run.

In scenario IC1, an increase in the whey consumption rate increases Chinese imports of U.S. whey, eliminating about 42% of the decline presented in Table 4. In scenario IC2, an increase in the whey consumption rate coupled with some rebound of the swine herd increases Chinese imports of U.S. whey further, eliminating an additional 11% of the decline presented in Table 4. In scenario IC3, the original decline in U.S. whey is fully recovered after removing the Chinese tariff increase on U.S. whey imports.

6 Conclusion

The model estimates large reductions in Chinese imports of U.S. whey (53%) and reductions to other non-U.S. whey imports (8%), with a smaller decline in non-U.S. whey due to the tariff imposition. The model also estimates large swine price increases (44%) and an increase in imported foreign swine (20%) to fill some industry demand, but it is nowhere near a one-for-one replacement of the lost Chinese herd. In the industry consolidation counterfactual, the model estimates a near rebound of Chinese imports of U.S. whey as the whey consumption rate rises post-ASF.

One limitation of this research is that data inputs used to establish the baseline of the model are estimates. We do not have separate whey data available for both pig feed and human consumption, so we make assumptions on the portion of whey imports used in feed. Similarly, we do not have live swine production data available, so we make an assumption on the pork-to-live weight conversion factor. Second, we do not explicitly model other piglet foodstuffs, such as lactose or soybean meal, and thus do not capture substitution effects to other piglet food sources. It is important to note that whey is not highly substitutable with soybean meal though, as each are consumed at different stages of the piglet life cycle.

This research could be extended to include a model of pork production and/or other meat varieties such as poultry to capture substitution to non-pork meat choices. The research could also be extended to explicitly model soybean meal as an important input into swine production. Additionally, further work on the industry consolidation counterfactual is needed to understand its full impact.

References

Armington, P. S. (1969). A Theory of Demand for Products Distinguished by Place of Production., *Staff Papers (International Monetary Fund)* **16**(1): 159–78.

Dim Sums Blog (2019). China's Plan to Restore Pork Supplies by 2021.
URL: *http://dimsums.blogspot.com/2019/12/chinas-plan-to-restore-pork-supplies-by.html*

Government of China (2018). Taxation Committee Announcement [2018] No. 5. Announcement of the Customs Tariff Commission of the State Council on Adding Tariffs to Imports of US$50 Billion.
URL: *http://gss.mof.gov.cn/zhengwuxinxi/zhengcefabu/201806/t20180616*$_2$930325*.html*

Government of China (2019). Taxation Committee Announcement [2019] No. 6. "Announcement of the Customs Tariff Commission of the State Council on the First Excluded List of Tariff Products Levied to the United States and Canada.
URL: *http://m.mof.gov.cn/czxw/201909/t2019091113384638.htm*

Haley, M. and Gale, F. (2020). African Swine Fever Shrinks Pork Production in China, Swells Demand for Imported Pork, *ERS Amber Waves* .
URL: *https://www.ers.usda.gov/amber-waves/2020/february/african-swine-fever-shrinks-pork-production-in-china-swells-demand-for-imported-pork/*

McCarthy, R. (2019). Rabobank: China's Pork Market Won't Recover Before 2025, *Meat+Poulty* .
URL: *https://www.meatpoultry.com/articles/22174-rabobank-chinas-pork-market-wont-recover-before-2025*

O'Keefe, M. (2020). Phase One U.S. trade deal with China positive step but U.S. dairy industry still needs tariffs lifted, *U.S. Dairy Exporter Blog* .

URL: *https://blog.usdec.org/usdairyexporter/phase-one-us-trade-deal-with-china-positive-step-but-us-dairy-industry-needs-tariffs-lifted-0*

Pan, C. (2018). Pork Quarterly Q3 2018, *Rabobank* .

URL: *https://services.rabobank.com/publicationservice/download/publication/token/w0xGGml9FN73*

Patton, D. and Gu, H. (2019). Swine Fever Toll in China may be Twice as High as Reported, Industry Insiders Say, *Reuters* .

URL: *https://www.reuters.com/article/us-china-swinefever-production-insight/swine-fever-toll-in-china-may-be-twice-as-high-as-reported-industry-insiders-say-idUSKCN1TV017*

Riker, D. and Schreiber, S. (2020). Trade Policy PE Modeling Portal, *U.S. International Trade Commission* .

URL: *https://www.usitc.gov/data/pe*$_m$*odeling/index.htm*