STATE-LEVEL SOYBEAN SUPPLY RESPONSE TO CHINA'S TARIFF

By

BIMAL KARKI

(Under the Direction of **Gopinath Munisamy**)

ABSTRACT

This study focused on estimating a state-level soybean supply model in the United States. Based on theoretical and empirical literature, eight economic determinants were identified for the soybean supply model, and data were obtained on those determinants for each of the 28 soybean producing states from 2000 to 2019. A recently developed method was adapted to quantify state-level exposure to China's import tariff on US soybean. Statistical analysis resulted in the selection of a double-log fixed effects model, which confirmed the statistical significance of all determinants. The coefficient on the primary variable of interest, state-level exposure to China's tariff, was statistically significant at the 10% level. It indicated that if the state-level exposure to Chinese tariff increased by 1% this year, then its soybean supply will decrease on average by 0.12% next year, all else constant. Additionally, world meat consumption was identified as a key shifter of state-level soybean supply.

INDEX WORDS: U.S. state-level soybean supply, China's tariff measure, world meat consumption, elasticity of soybean supply, US-China soybean trade.

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BIMAL KARKI

B.Sc., Tribhuvan University, Nepal, 2017

A Thesis Submitted to the Graduate Faculty of The University of Georgia in Partial Fulfillment of the Requirements for the Degree

MASTER OF SCIENCE

ATHENS, GEORGIA

2022

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BIMAL KARKI

Major Professor: Gopinath Munisamy
Committee: Octavio A. Ramirez
Jeffrey D. Mullen

Electronic Version Approved:

Ron Walcott
Vice Provost for Graduate Education and Dean of the Graduate School
The University of Georgia
May 2022

DEDICATION

To the farmers of the U.S. and the world. Thank you, for feeding us.

ACKNOWLEDGEMENTS

I am immensely grateful to Dr. Gopinath Munisamy, my major professor, who never stopped believing in me and inspired me to become a better economist. His valuable insights and detailed suggestions are the pillars behind making this thesis possible. Without his indispensable guidance, this study would have been futile. I am very grateful to Dr. Octavio Ramirez and Dr. Jeffrey Mullen, for their guidance and unwavering support towards me, throughout my MS program and in this thesis. I am thankful to the UGA Department of Agricultural and Applied Economics for funding my MS study.

My head bows down in respect to all my teachers and professors, who made me a better student by bestowing their knowledge upon me.

I am thankful to USDA, FAO, EWG, and OECD for that they maintain a vast library of data, freely accessible to the public.

I express my gratitude; to my parents, without their sacrifices, I am nothing; to my wife Shrijana, who is always beside me in my highs and lows and inspires me to become a better man; to my brothers, who are the sources of my courage; to my friends in my hometown, whose support gives me hope; to my roommates, who are now my second family in the U.S.

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CHAPTER 1

INTRODUCTION

1.1 Drivers of Soybean Industry

The world soybean industry is an intricate network of exporting and importing nations for whole-soybean, soybean meal, and soybean oil worldwide, each motivated by their self-interests. Major exporters/producers include countries like the U.S. and Brazil, while significant importers/processors are Asian nations like China, Japan, and also, to some extent, the European Union (E.U.). Soybean is the fourth largest crop produced in terms of volume worldwide, and its global trade accounts for 10% of the total value of worldwide agricultural trade (Lee *et al*., 2016).

The rise in per capita income and rapid urbanization (especially in developing nations) indirectly drove the growth in the soybean industry (Vandenvorre, 1964; Goldsmith, 2008; Lee *et al*., 2016). The former progress led to a brisk shift in peoples' diet from staples towards meat and other high-value agricultural products. To meet the meat demand of the growing population, livestock producers, especially in developing nations, turned themselves into massive poultry and pig producers. Consequently, this led to a rapid increase in demand for high-protein feed among poultry producers and livestock raisers worldwide. In essence, increasing demand for high-protein livestock feed mostly drove the rapid growth in soybean production/supply. Another significant factor that affects soybean supply and trade is the policies regarding soybean products' and livestock products' export and import, adapted by different importing and exporting nations (Lee *et al*., 2016; Ates and Bukowski, 2021).

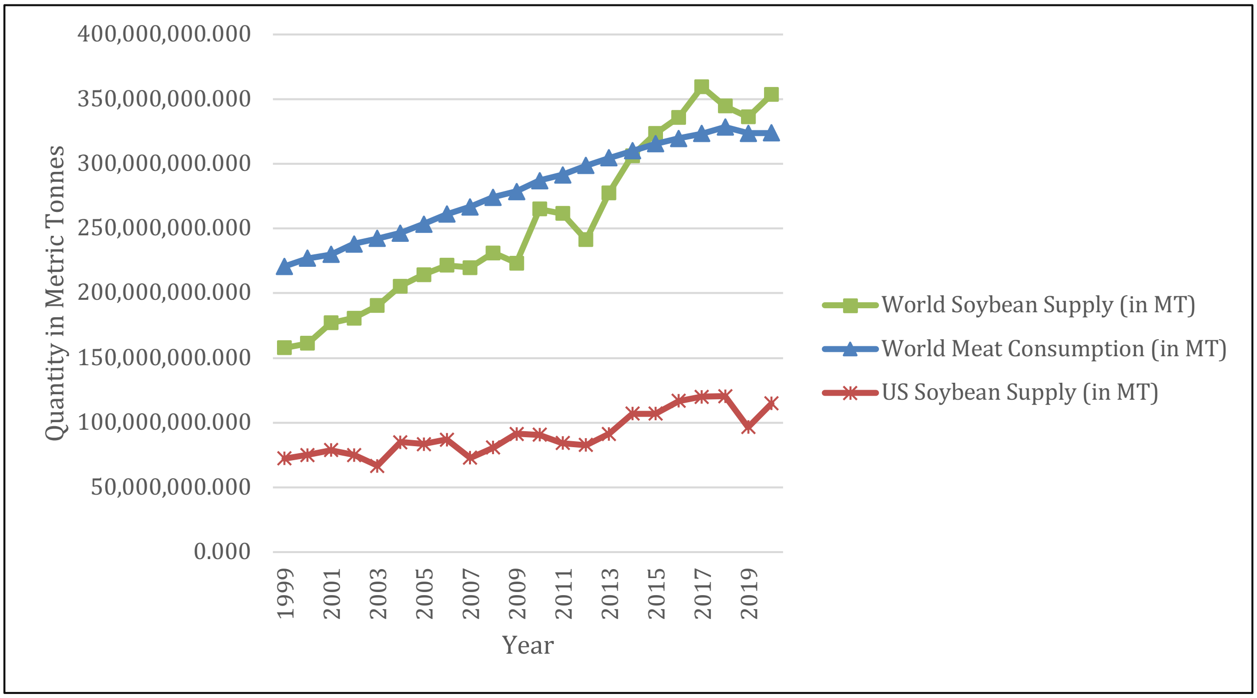

Figure 1. 1: Soybean supply/production (world and the U.S.), and world meat consumption.

(Source: FAOSTAT, 2021; OECD Database, 2021; USDA, 2021)

China is the current dominant soybean consumer and importer globally, accounting for more than 60% of world soybean imports (Gale *et al*., 2019), and this is mainly due to its consumers' rising per capita income and shift in diets (Lee *et al*., 2016). The nation has shown a significant increase in demand for livestock feed in order to maintain and grow its massive pig herds and poultry industry. This heightened demand for livestock feed has led China to become an importer of such a massive scale. Furthermore, since 1995, the Chinese government adopted a '95% grain self-sufficiency' policy regarding which commodity support programs were designed and implemented gradually. Significantly during 2008–2012, under the former policy, the Chinese government hiked its support for rice, wheat, and corn, whereas that for the soybeans were maintained relatively lower. Over the years, this policy altered the Chinese farmers' production decisions to produce more grains and reduce the production of soybeans. Due to the former Chinese policy coupled with lower import tariffs for soybeans (at 3%), China became a soybean importing giant globally. Additionally, relatively higher import tariffs than soybean for soybean meal (at 5%) and soybean oil (at 9%) flourished the nation's oilseed crushing industry, making it one of the largest in the world (Lee *et al*., 2016).

1.2 Soybean and its uses

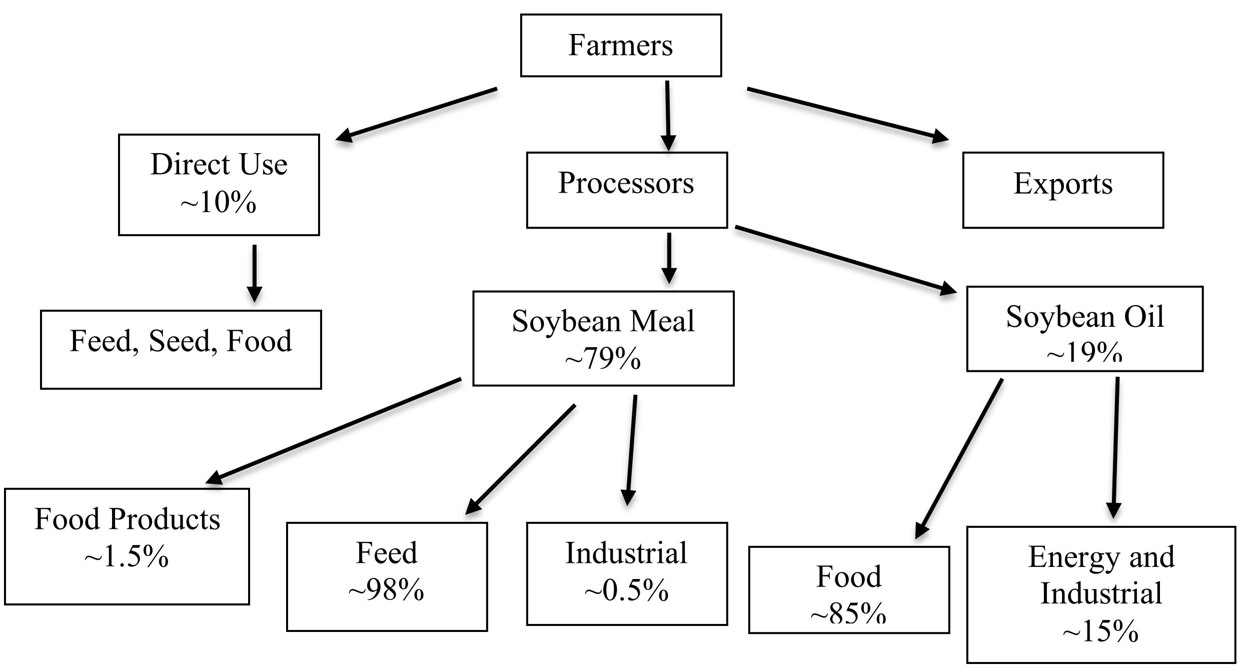

Figure 1. 2: Soybean complex: structure of the Industry

(Source: US International Trade Commission, 2003; Goldsmith, 2008)

Soybean is widely cultivated throughout the world, mostly in the U.S., Brazil, Argentina, and other regions of the world. Soybean is a valuable field crop, used mostly to process into livestock feed because of its richness in protein (35-40%). Soybean is considered the "king of beans," a globally traded agricultural commodity. According to the World Wildlife Fund (2020), the global soybean production has increased 15 folds since the 1950s. In 2017, The Financial Times called soybeans the "crop of the century", observing it's rapidly increasing global production and trade (Meyer *et al*., 2017).

Direct consumption of soybeans by humans is limited to a relatively small amount, and almost 80–85% of the total soybean production goes for further processing into making soybean meal and soybean oil (Lee *et al*., 2016). While the majority of the demand for soybean comes in the form of soybean meal, a relatively smaller fraction of soybean goes into making soybean oil, which is either directly consumed as cooking oil, or goes towards further processing soybean oil into making biofuel (Goldsmith, 2008; Lee *et al*., 2016).

Almost half of the soybean produced in the U.S. is shipped to domestic crushing industries, and slightly less than half of that total produced is exported to Asian markets like China, Indonesia, Bangladesh and others. Crushing is a process which results in two main products--soybean meal and soybean oil. While soybean meal is the most important source of protein for the livestock industry, soybean oil accounts for more than half of all vegetable oils consumed in the U.S. (Curran, 2020).

1.3 Soybean Production in the U.S.: Brief History and Present

Soybean was first introduced into North America by a former East India Company sailor, Samuel Bowen, in 1765. It was first grown by Henry Yonge with seeds provided by

Bowen in Skidaway Island and then by Bowen himself in Savannah, Georgia, in 1765 (Mims, 2014). Although introduced to the U.S. in 1765, soybean was mainly grown to be used as forage crops until the 1910s (National Soybean Research Laboratory, 2003) and did not hold the enormous economic value it has today.

After World War II, the boom in world population drove the demand for planted-based livestock feed, which had the prospect of reducing cost of production for livestock producers (Vandenvorre, 1964). Coupled with the demand for healthier cooking oil, it gave rise to massive soybean production in the U.S., marking the nation as the largest producer and exporter of soybean globally (Goldsmith, 2008). While Brazil's soybean production began to compete and some years moderately surpassed that of the U.S. in the late 2000s, the U.S. is still a massive producer and exporter of soybean. Before China, the major exporting destinations of U.S. soybeans were the European Union and Japan.

Soybean in the U.S.-Midwest region is a spring crop, seeded during May and June, while harvesting is carried out from late September through October (USDA NASS, 2020). Soybeans after harvest are shipped for exports to different nations, while domestic crushing industries also receive soybeans for manufacturing soybean meal and soybean oil. The producers stockpile any excess of soybean produced in the U.S. in the hope of selling it when market prices are favorable (Swearingen and Janzen, 2021).

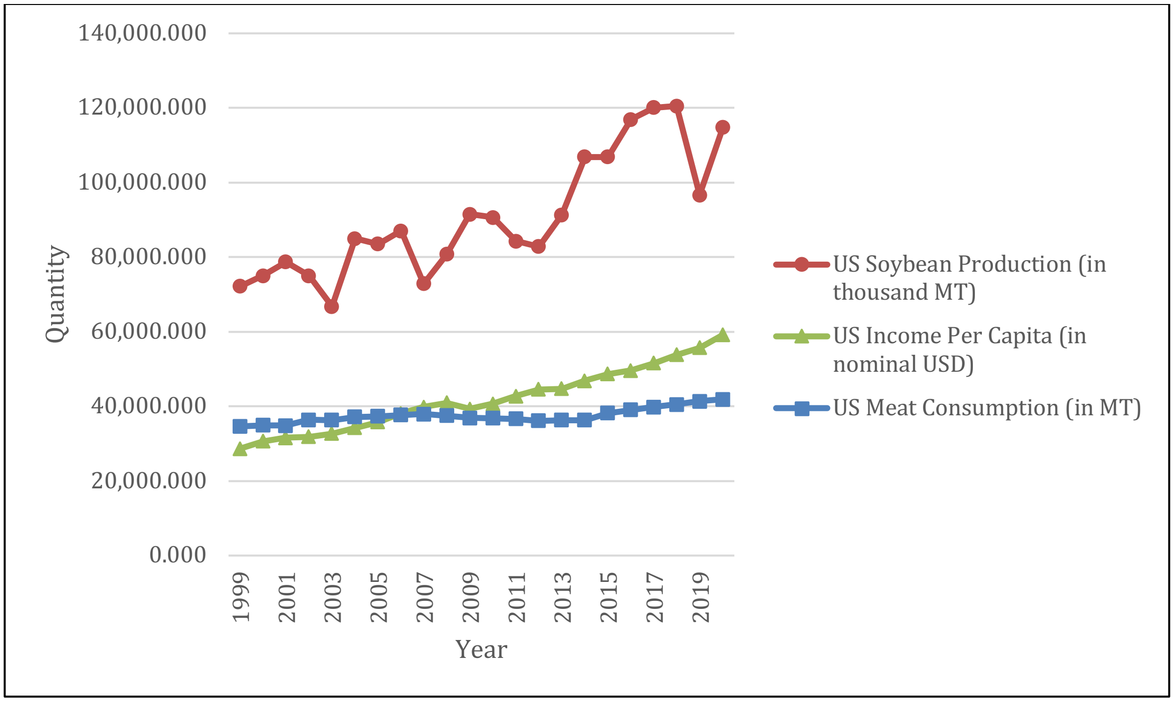

Figure 1. 3: Major domestic drivers of U.S. soybean production

(Source: FRED, 2021; OECD Database, 2021; USDA, 2021)

In the 2017/18 marketing year, soybeans accounted for approximately 30% of the total harvested cropland in the U.S. (Cowley, 2020). Soybean is the second largest crop today in the U.S., preceded by corn in terms of acreage and value (USDA NASS, 2020). Due to the rise in demand for poultry and pig products, soybean producers worldwide including the U.S. have witnessed massive demand for soybean based livestock feed (Goldsmith, 2008; Lee *et al*., 2016). Soybean production in the U.S. is affected by its domestic demand and foreign demand for soybean. The domestic demand for soybean comes in the majority from its livestock sector in the form of soybean meal, and demand for soybean oil. Although the domestic consumption of meat in the U.S. is slowly and steadily growing, soybean production in the U.S. is additionally fueled by world demand for soybean products. Production of U.S.

soybeans based upon foreign demand has led the growth of U.S. soybean production to become dependent upon foreign exports (Gale *et al*., 2019; Johnson and Zeng, 2021).

The U.S. and Brazil combined accounted for over 80% of the supply of global soybean exports (Gale *et al*., 2019). Although U.S. soybean producers have had the lower comparative advantage for soybean production relative to the South American soybean producers since the 2000s, the U.S. soybean production has risen due to rising global (and domestic) demand for meat (Goldsmith, 2008). The lower comparative advantage for U.S. soybean producers (in the U.S. heartland) arises mainly from the higher cost of production per hectare, which is $1095 per hectare, and that for Brazil (in Mato Grosso) is $839 per hectare (Gale *et al*., 2019). A noticeable difference in operating costs and fixed cost between soybean producers of two nations have been observed by researchers. While the U.S. soybean producers/suppliers have lower operating costs, they deal with higher fixed costs such as land, labor, and machinery costs than that of Brazil. However, in the context of soybean producers worldwide, the U.S. soybean producers maintain comparative advantages due to one of the world's lowest operating and logistics costs.

Despite competition from its South American counterpart in soybean production and exports, U.S. soybean exports to China have displayed exponential growth in the last two decades, mainly attributed to the different times of a calendar year for harvest and export between the two competitors. U.S. soybean exports to China exhibit peak quantity during December–January of the year, whereas that of Brazil to China shows peak export quantity during June-July of a marketing year (Gale *et al*., 2019).

Large-scale domestic soybean production in the U.S. can also be attributed to a rise in soybean yield, a higher number of 50-50 corn-soybean rotations, and lower production costs

(Ates and Bukowski, 2021). Rising yields reduced per-bushel production costs and thus increased profitability for the soybean producers. The Mid-west region of the U.S. has higher yields than Eastern and Southern region producers, partly leading to a concentration of more than 81% of U.S. soybean acreage in that region in 2020.

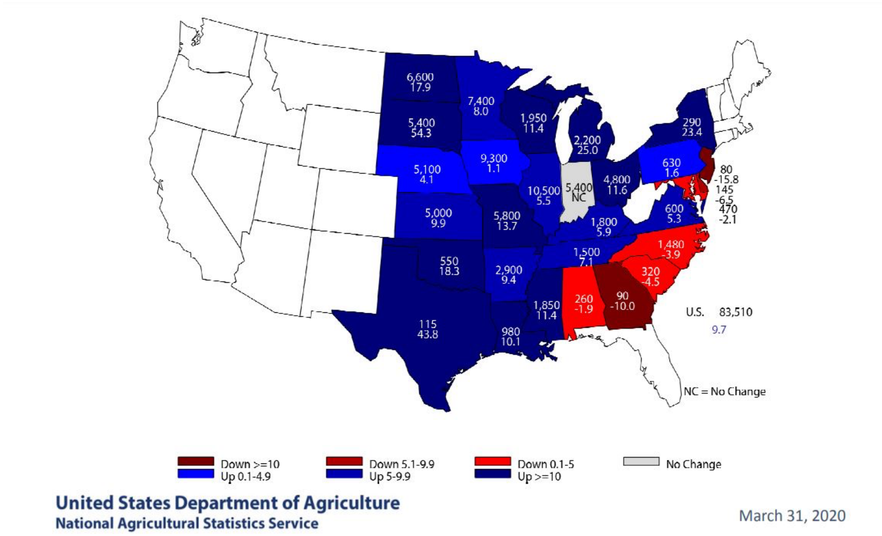

Figure 1. 4: Major soybean producing states in the U.S. in 2020.

(Source: USDA NASS, 2020)

Family-owned farms characterize soybean producers/farmers in the U.S. as sole proprietorships, partnerships, and occasionally some corporations. According to the Census of Agriculture 2017, the U.S. had 303,191 farms actively engaged in soybean production. Soybean producers in the U.S. usually reduce average costs by spreading fixed costs over large production volumes (Curran, 2020). Coupled with higher crop yields, producers can lower the per-unit cost in soybean production, enabling them to broaden profit margins. However, the profits realized by U.S. farmers directly depend upon soybean prices which in turn is determined by various (domestic and international) factors that are not always in control of the soybean farmers. Soybean is an agricultural commodity pertaining to competitive markets, where producers are usually the price takers.

In the fiscal year 2016/17, the U.S. produced 116.9 million metric tons of soybeans, of which approximately 36 million metric tons were exported to China (USDA ERS and USDA FAS, 2021). The U.S. exported 57.79 million metric tons of soybeans to the world in the same fiscal year and China was the first destination which accounted for 62.37% of total U.S. soybean exports that year. The U.S. also reported exporting soybeans to the European Union, Mexico, and other Asian countries; 8%, 19%, and 7% that same fiscal year (Gale *et al*., 2019). However, the soybean export to China sharply diminished in 2018, the year of the Trade-war between the U.S. and China, following massive retaliatory import tariffs from China for U.S. soybeans. The U.S. soybean suppliers were exposed to a decline in market price, and many of them resorted to stockpiling their harvest with the hopes to sell it when market prices turned back to normal. This trade war led to increased demand for stockpiling among U.S. soybean farmers and further raised stockpiling costs (Swearingen and Janzen, 2021).

The majority (84.1%, according to Census of Agriculture 2017) of U.S. soybeans producing farmers are from the Mid-west regions (Illinois, Indiana, Iowa, Kansas, Michigan, Minnesota, Missouri, North Dakota, Nebraska, Ohio, South Dakota, and Wisconsin) and have comparatively lower operating costs when compared to global competitors (Zhu, 2012; USDA NASS, 2019; Gale *et al*., 2019). In 2017, the Mid-west region was responsible for producing more than 34% of the world's soybean and 33% of the world's corn (UN FAO, 2017). The U.S.'s six largest soybean exporting states are Illinois, Iowa, Minnesota, Indiana and Nebraska, and Ohio (USDA FAS 2021). For decades, the U.S. has had a developed supply chain for soybeans, including production, transportation, and marketing. Moreover, contrary to its global soybean exporting competitors in South America, the U.S. has broader market participation, stable currency, and a stable political system that provides a better trade environment for its soybean producers and exporters (Zhu, 2012, p.12).

In 2001, China joined the World Trade Organization (WTO), officially opening its markets for trade with the world. Official access to trade with China led to a substantial export shift for U.S. soybeans from Europe and Japan towards China, attributed to that nation's rising per capita income and growing demand for livestock feed. This shift in production and export of U.S. soybean to China over the years is observable in Table 1.1.

In the U.S. agricultural commodity sector, including soybean, a decrease in the price of commodities produced due to domestic or foreign governments' agricultural policies could lead to decreased farm income, which might lead to an undue change in farming decisions, delayed farm equipment purchase, delayed payments on farm loans, and other ripple effects throughout the farming sector. In their research on the U.S.-China trade war, Elobeid *et al*. (2019) signaled that Chinese retaliatory tariffs on U.S. soybeans, if prolonged, could ultimately lead to a decline in soybean production, which further leads to loss of jobs, a decline in labor income, and direct or indirect reduction in welfare for people associated with the U.S. soybean industry. Soybean being a major agricultural commodity of the U.S., the production and export of soybean is critical to farm profitability and regional economic activity across a large portion of the U.S. (Schnepf, 2019).

Table 1. 1 US Soybean Supply and Exports

Year	US Total Production (in MT)	Total Export to World (as a percentage of total US soybean production)	Total Export to China (as a percentage of total US soybean production)	US Soybean Export to China as a percentage of US Soybean Export to the World
1999	72,230,756.67	32.03%	2.60%	8.13%
2000	75,062,874.25	35.95%	6.96%	19.38%
2001	78,679,422.97	36.50%	6.90%	18.92%
2002	75,017,610.23	36.89%	6.48%	17.56%
2003	66,789,466.52	46.16%	16.63%	36.03%
2004	85,024,224.28	29.56%	11.05%	37.40%
2005	83,515,024.50	30.54%	11.29%	36.98%
2006	87,009,417.53	32.38%	11.86%	36.62%
2007	72,866,548.72	40.86%	16.15%	39.53%
2008	80,756,859.01	41.87%	20.44%	48.82%
2009	91,478,796.95	44.13%	24.94%	56.51%
2010	90,672,455.09	46.67%	26.81%	57.45%
2011	84,299,918.35	40.77%	24.54%	60.19%
2012	82,799,237.89	52.68%	31.63%	60.04%
2013	91,371,910.72	43.08%	26.87%	62.37%
2014	106,915,351.12	46.36%	28.83%	62.19%
2015	106,880,212.30	45.05%	25.50%	56.61%
2016	116,943,277.08	49.42%	30.82%	62.37%
2017	120,077,109.42	46.02%	26.39%	57.34%
2018	120,526,673.92	38.31%	6.83%	17.83%
2019	96,676,864.45	54.15%	23.38%	43.18%

(Source: USDA ERS and FAS, 2021; and Author's Calculations)

From the pretext that the U.S. soybean production considerably relies on exports to the world and especially China, the need to understand the U.S.-China trade war and impact of Chinese retaliatory tariff arises. In 1999, the total export of U.S. soybeans to China was merely 2.6% of its total production; however, in 2020, that was approximately 30.12% of the total U.S. soybean production. Post-2001, after China joined WTO, the U.S. briskly increased its soybean exports to China, attributed to China's import tariffs favoring soybean imports and the rise of massive Chinese soybean crushing industry. For the first time in 2010, U.S. soybean exports to China surpassed a quarter of its total production, and the trend approximately continued until the beginning of the US-China trade war in 2018. Albeit the export of U.S.-produced soybean to China exhibits seasonal patterns, peaking during December–January of a given marketing year, the aggregate annual export of U.S. soybeans to China fell to 6.83% of the total U.S. soybean production in 2018 from 26.39% of that in 2017.

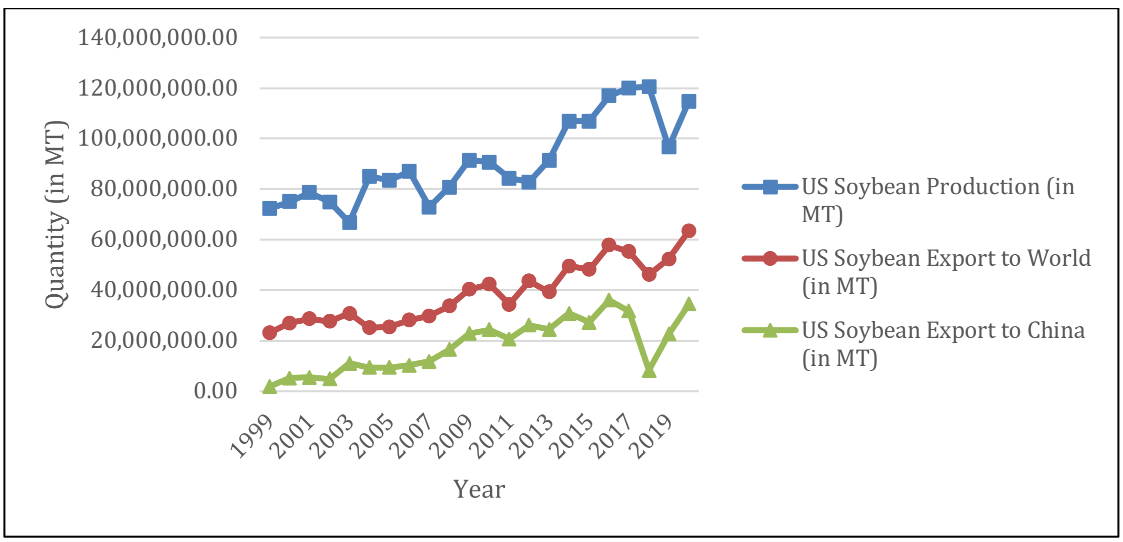

Figure 1. 5: US soybean production and Exports

(Source: USDA NASS, 2021; USDA FAS, 2021)

Upon observing figure 1.5, the last two decades indicate almost parallel trends among the rise in U.S. soybean production and the U.S. soybean export to China. Just a visual observation of how much U.S. soybean producers rely on foreign exports, especially China. This dependency of U.S. soybean producers/suppliers on China's imports makes the U.S. vulnerable to disruptions in Chinese import tariffs (Zheng *et al*., 2018; Gale *et al*., 2019; Cowley, 2020; Adjemian *et al*., 2021). Due to retaliatory tariffs from trade-war, US soybean producers were exposed to lower price and lower export of soybean, leading to hike in operating and farm machinery costs, ultimately reducing farm profitability for US soybean producers. Short-run price decline was the major contributing element which led to a 16% decrease in US net farm income in 2018 compared to 2017 (Regmi, 2019).

As observed from Table 1.2, in terms of the value of soybean export to different nations from the U.S., no other nation comes near the magnitude of the value of soybean exported to China, except the year 2018, when during the US-China Trade War, China imposed higher than routine tariffs on U.S. soybeans. Even then, China maintained its position as the first destination for U.S. soybean exports, moderately surpassing the E.U. and the U.K.

1.4 The U.S.-China Soybean Trade War and its Effects on Soybean

On March 23, 2018, President Donald Trump's administration, under Section 232 of the Trade Expansion Act of 1962, imposed a 10% import tariff on all aluminum imports except from Australia and Argentina, and a 25% tariff on all steel imports except from Australia, Argentina, Brazil and South Korea (Hopkinson, 2018, p.2, 2019, Wong and Koty, 2020). Moreover, during 2018–2019, the U.S. imposed increased tariffs on certain goods imported

Table 1. 2: Top 10 Foreign Markets for U.S. Soybeans (values in millions of US dollars)

Country	2016	2017	2018	2019	2020
China	14,203	12,224	3,119	8,005	14,159
EU+UK	1,899	1,637	3,078	1,953	1,940
Mexico	1,462	1,574	1,818	1,878	1,895
Egypt	100	364	1,164	995	1,475
Japan	1,000	973	927	971	1,063
Indonesia	988	922	998	864	884
Taiwan	579	586	854	685	604
Thailand	362	467	593	524	568
Bangladesh	228	391	434	388	481
Vietnam	341	288	469	262	420
All others	1,678	2,029	3,603	2,138	2,192
Total Exported	22,839	21,456	17,058	18,663	25,683
China's percentage of total value of exported US soybeans.	62.18%	56.97%	18.28%	42.89%	55.12%

(Source: Trupo, USDA FAS, *Agricultural Export Yearbook*, 2020, p.27)

from China in "Four Waves" after an investigation based on Section 301 of the Trade Act of 1974 resulted in the conclusion that intellectual property rights and technology transfer protocols were violated by policies of the Chinese government (Flaaen *et al*., 2021, Hopkinson, 2018).

In retaliation to the Section 232 tariffs, major trading nations including China, Canada, Mexico, the European Union, and Turkey retaliated with tariffs during the summer of 2018 on U.S. foods and agricultural commodities. Among various trading nations, China first imposed a retaliatory tariff ranging 5–25% on more than 800 U.S. food and agricultural commodities, which went into effect on April 2, 2018. On July 6, 2018, in response to Section 301 tariffs, China applied retaliatory tariffs to more than 500 additional agricultural and food products, this time including soybeans. An additional list of retaliatory tariffs on more than 360 US food and agricultural exports was imposed on September 24, 2018 (Hopkinson, 2018, p.3).

According to Bown (2021), the US-China trade war has proceeded in five significant stages from 2018 to 2021. The first stage was the first six months of 2018, whereby tariffs were seen increasing moderately; the second stage was from July to September 2018, whereby tariffs were seen increasing sharply on both sides. During this time, the U.S. tariff for goods imported from China increased from 3.8% to 12% on average, whereas the Chinese retaliatory tariffs for U.S. goods increased from 7.2% to 18.3% on average. In the third stage, which lasted from September 25, 2018, to June 2019, tariff rates remained almost unchanged on both sides. In the fourth stage, which lasted from June to September 2019, the two nations again imposed each other with increased tariffs. The current stage is the fifth stage, where phase one agreement is in effect; however, no parties have lowered their escalated tariff rates[1], and this trade war seems to be the new normal (Bown, 2021, Lee, 2021, Hsu, 2021).

In 2018, the year U.S. soybeans faced China's retaliatory tariffs, U.S. soybean exports to China declined to a mere $3.1 billion USD from $12.2 billion, as observed from table 1.2. The same year, U.S. soybean future prices dropped more than 7% to $8.145 per bushel, their lowest since March 2009 (Cheng, 2018). However, a study done by Giri *et al*. (2018) argues that irrespective of the Chinese retaliatory tariffs on U.S. soybeans, the record harvest of the

[1] Based on an article from CBS "*Biden has left Trump's China tariffs in place. Here's why*". The article was posted on March 25, 2021.
https://www.cbs58.com/news/biden-has-left-trumps-china-tariffs-in-place-heres-why

crop in 2018 would have resulted in lower prices with almost certainty. Their research provides a notion that the anticipated Chinese retaliatory tariff may have been a part of the price decline; however, it is likely that the price decline was a normal response to the increased output that year. U.S. soybean exports did increase to other avenues, namely European Union and other countries, in 2018; nonetheless, those exports were not enough to replace that to China (Hopkins, 2019, Regmi, 2019, Cowley, 2020).

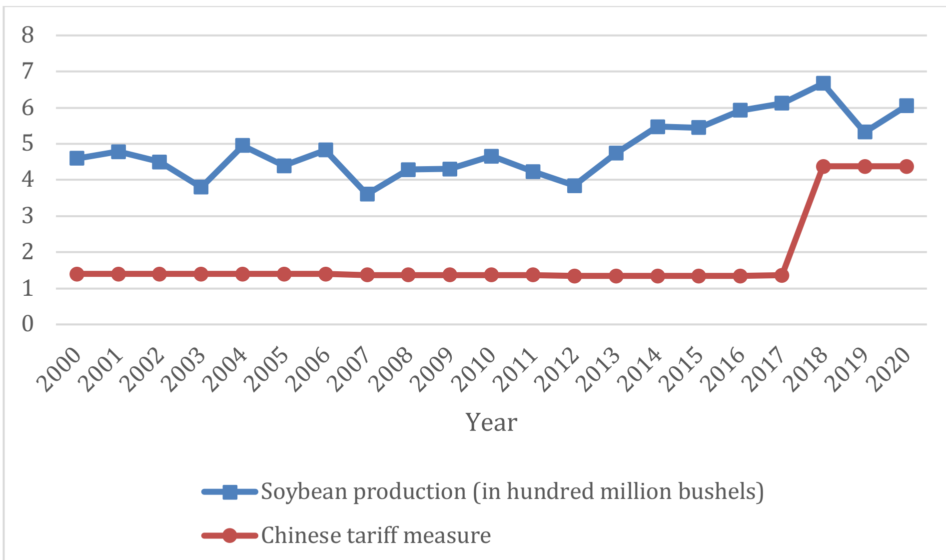

Figure 1. 6: Soybean production vs. Chinese tariff measure in Illinois

(Source: USDA NASS, 2021; Inouye and Ward, 2020)

During 2018/19 marketing year, with retaliatory tariffs in full effect, in order to meet its annual soybean demand, China swiftly turned to alternative exporters such as Brazil, Argentina, and Paraguay (Morgan *et al*., 2022). This is corroborated by the fact that Brazil's soybean export accounted for 46% and 53% of China's total soybean imports in 2016 and 2017 respectively, while that of which spiked to 76% in 2018 (Regmi, 2019).

Although the Chinese retaliatory tariffs remained in place, the U.S. and China signed Phase-One Agreement in January of 2020, which facilitated tariff exemptions for many traded goods including soybeans, driving up the amount of soybeans exported to China in 2019 and 2020. The export of U.S. soybean to China increased by approximately $5 billion and $11 billion in comparison to that of 2019 and 2018 respectively (USDA FAS, 2021). An exemption process for the retaliatory Section 301 tariffs under the bilateral Phase-One agreement was one of the main drivers behind significant increase in China's import of U.S. soybean.

Table 1. 3: Chinese Tariffs on Soybean Products

HS Code	Description	MFN Rate	Section 232	Section 301	Total Applied Tariff
	Implementation Date	Jan 1, 2020	April 2, 2018	Feb 14, 2020	Feb 14, 2020
12011000	Soya Beans For Cultivation	0%	-	5%	25%
12019010	Yellow Soya Beans, Not For Cultivation	3%	-	27.5%	30.5%
12019020	Black Soya Beans, Not For Cultivation	3%	-	25%	28%
12019030	Green Soya Beans, Not For Cultivation	3%	-	5%	8%
12019090	Other Soybeans	3%		5%	8%
Tariff Schedule on Soybean (Source: Zheng et. al, 2018; Inouye, 2018; USDA, 2018)					
120190	Soybeans; other than seed, whether or not broken	3%	-	-	28%

(Source: USDA-FAS, GAIN Report Number CH2020-0106, August 5th, 2020)

Additionally, China had one of the fastest recoveries from Covid-19 leading to strong demand for U.S. agricultural products including soybean, cotton, wheat, and corn. The third driver was significant reduction in African Swine fever (AFS) among its pig population in China, following which China began rebuilding its pig population, thus increasing the import of soybean from the U.S. (USDA FAS, 2021).

In January of 2018, before the trade war, the Chinese applied tariff rate on U.S. exports stood at a trade-weighted average of 8%, and that of the U.S. on Chinese exports stood at a trade-weighted average of 3.1%. Whereas, in January of 2021, with the increased tariffs, the Chinese applied tariff rate on US exports stood at a trade-weighted average of 20.7% and US applied tariff rate on Chinese exports stood at a trade-weighted average of 19.3% (Bown, 2021). Amongst other traded commodities, the applied Chinese import tariff on US soybean hiked up to 28% (Zheng et. al, 2018).

1.5 U.S.-China Phase One agreement

The U.S.-China trade-war saw its highest escalation in the fall of 2019, and arriving at the end of 2019, the giant trading partners agreed to deescalate the ongoing trade-war by assisting each-other towards slowly moving back to pre-trade-war tariffs and normalizing trade conditions. This agreement was named 'Phase-One Agreement', which was agreed upon and signed by both trading partners in January 2020 (Bekkers and Schroeter, 2020, p.1, Morgan *et al*., 2022).

The agreement officially took effect on February 14, 2020 (Lester and Zhu, 2021) with the intention to address structural barriers and to further open the Chinese market to U.S. agricultural products. China has made a number of commitments including the annual purchase of $40 billion worth of U.S. agricultural goods including seafood in 2020 and 2021 each, and additionally, substantially increased imports of industrial products, natural resources, and services from the U.S. The aggregate commitments made by China are approximately twice the amount of pre-trade dispute levels (Morgan *et al*., 2022). China has agreed to uphold an efficient, transparent, and science-based regulatory process for evaluating and authorizing biotech products. China has also agreed to diligently address sanitary and phytosanitary (SPS) protocols regarding various agricultural products.

After the Phase One Agreement between the U.S. and China, China through its State Council's Customs Tariff Commission granted exemptions of retaliatory tariffs on several of the U.S. products including soybeans, pork, liquefied natural gas, crude oil, etc. Morgan *et al*., (2022) reported that overall imports of U.S. products by China hiked by more than 110% ($28 billion) after the agreement. The researchers also reported that export quantity of the U.S. products receiving official tariff exemptions increased by 118% and that of the products not receiving official tariff exemption increased by 83%. However, the researchers are not certain if the rapid increase in import of U.S. agricultural products can only be attributed to Phase-One agreement, as it is likely that partial driver of increased imports could be due to China's recovery from Covid-19 as well as recovery from the African Swine Flu (ASF) for its pig herds. Furthermore, the researchers argue that even after hitting record numbers in U.S. agricultural exports to China, market shares still remain to recover to what was in 2017.

1.6 US Government's Commodity Support Programs for Soybeans Producers

Economic theory suggests that a nation's policies towards agricultural commodities can alter the production decision of its farmers. For example, China adapted '95% grain self-sufficiency' policy in 1995, and with a gradual increase in support for the production of grains compared to oilseed such as soybeans, the Chinese soybean producers shifted production towards grains. Consequently, Chinese consumers of soybeans (i.e., their livestock producers mainly) rely heavily on the import of soybeans in addition to domestic production to meet their demand for soybean meal and soybean oil.

Before the trade war in 2018, the U.S. government provided subsidies to its soybean farmers in the form of Direct Payments (2003-2008), Production Flexibility Contracts (1996 - 2002), Crop Insurance Subsidies, and Price Support Payments (EWG, 2020). However, with the new 2018 Farm Act, oilseeds, including soybeans, are covered under Title I – Crop Commodity Programs (Ates and Bukowski, 2021) that include the Agricultural Risk Coverage (ARC), the Price Loss Coverage (PLC), and the Nonrecourse Marketing Assistance Loan Program (MAL). USDA's Farm Service Agency (FSA) is tasked with delivering these commodity support programs to eligible U.S. soybean farmers. A farmer's eligibility is based on (but not limited to) their adjusted gross income, conservation and wetland protection compliance, and verification of their participation in soybean farming. Since 2019, U.S. soybean farmers/producers have been allowed to choose between ARC and PLC on a commodity-by-commodity basis, and producers are eligible to receive payments on 85% of planted soybean's base acres. For the PLC program, a legislative effective reference price is preset for a given marketing year, and producers will be paid if soybean's market prices fall below the preset price. For the ARC program, the same effective legislative price is referenced, and payments are made to soybean producers if a county's crop revenue falls below 86% of that county's benchmark revenue. Moreover, both PLC and ARC also consider the soybean farmers' yield to decide if and when to make payments to the soybean producers.

MAL program of the USDA offers soybean farmers a short-term loan if the market prices for soybeans during harvest are not favorable, allowing soybean farmers to delay the sale of soybean until market prices improve (Ates and Bukowski, 2021).

After the trade-war initiated in 2018, USDA developed and announced a trade-assistance program under Section 5 of Commodity Credit Corporation Charter Act in order to assist U.S. farmers whose commodities (including soybean farmers) were under direct impact of the Chinese retaliatory tariffs (Farm Service Agency, 2018; Regmi, 2019; Rabinowitz and Munisamy, 2019). The trade assistance package included three major programs; the first was the Market Facilitation Program (MFP) designed to provide direct payments to the trade-war impacted U.S. farmers. The second program was the Food Purchase and Distribution Program (FPDP), which was designed to allow USDA to purchase surplus farm commodities, and the third program was the Agricultural Trade Promotion Program (ATP), which was designed to assist in new export market development for U.S. farmers/producers.

The Market Facilitation Program, under which an ad hoc payment was made to trade-war impacted U.S. farmers, was one of the major research topics for many researchers studying questions relevant to the US-China trade war. USDA announced up to $12 billion and up to $16 billion in trade assistance to the farmers (including soybean farmers) with impacted commodities in 2018 and 2019. The aggregate annual MFP payments made by USDA to the impacted U.S. farmers accounted for $5.127345 billion, $14.202 billion, $3.732 billion, and $8.485 million during 2018, 2019, 2020, and by February 5, 2021, respectively (Schnepf, 2019b; Schnepf and Rosch, 2021; USDA ERS, 2021).

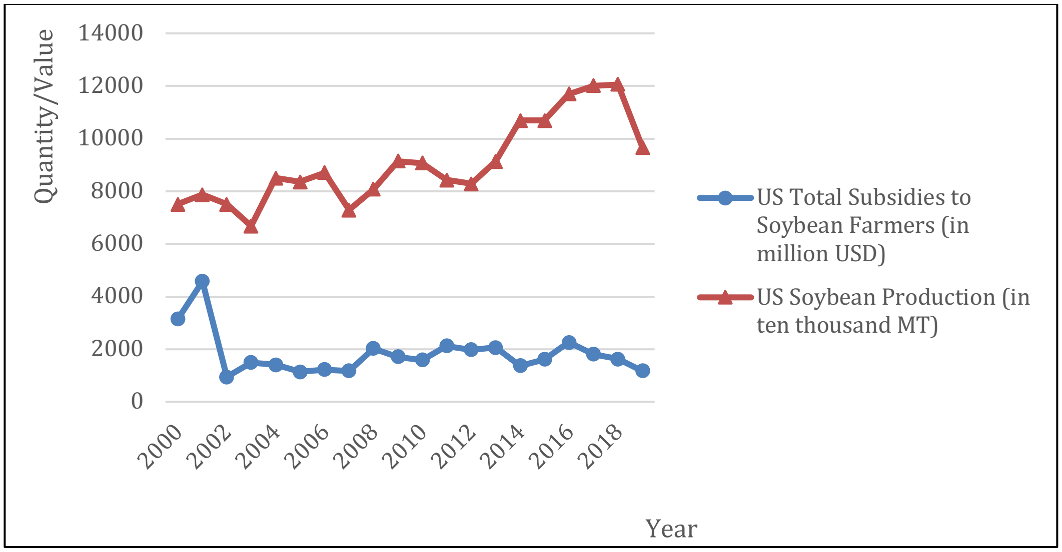

Figure 1. 7: US Soybean Subsidies to Producers and US Soybean Production

(Source: USDA NASS, 2020, EWG 2021)

Researchers assessed that the short-run impacts of the Chinese retaliatory tariffs might have been well compensated by the direct payments to the U.S. soybean producers; however, the long-run impacts such as future trade relations and opportunities might not be covered by these ad hoc government payments (Giri *et al*., 2018, Janzen and Hendricks, 2020). Furthermore, USDA and other independent researchers have found that aside from compensating U.S. farmers in the short-run, the MFP payments had no significant impact on production decision of the soybean farmers, as the payments were made after the planting operation of soybean was completed in each marketing year (Giri *et al*., 2018; Janzen and Hendricks, 2020; Swearingen and Janzen, 2021; USDA ERS a, 2021; Morgan *et al*., 2022).

1.7 Rationale of Study

The motivation for conducting this research stems from the broader desire to understand how agricultural policies and international demand impact producers/farmers. Trade theory suggests that domestic agricultural policies developed and implemented by any nation can significantly alter its farmers' production decisions. The import and export policies of a nation can alter both its domestic producer and consumer behavior and impact producers and consumers of other nations. In addition, the foreign demand for a commodity can also alter the production decisions of domestic farmers/suppliers. Due to the sharply increasing proportion of U.S.-produced soybeans exported to China beginning in 2001, the need arises to estimate an empirical supply model for U.S. state-level soybeans arises, using past two decades of data.

This research has been attempted to identify economic determinants of U.S. state-level soybean supply. In particular, it seeks to examine the impact, if any, of China's tariffs on state-level soybean production. From past national-level studies, it could be assumed that comparatively larger soybean-producing states of the U.S. were certainly impacted by the Chinese tariffs, however, from that it remains unclear if, on average, the smaller soybean-producing states were also impacted. This study aims to reveal the response of state-level soybean supply not only for the Mid-west (larger) soybean-producing states but also that of the smaller soybean-producing states, on average. Moreover, this study aims to identify the previously unexplored effect of world meat consumption, a proxy for domestic and foreign demand of livestock feed (majority of which comes from soybean), on state-level soybean supply. Given that world meat consumption and thus demand for livestock feed is projected by USDA (2021) to rise in the coming years, by identifying this variable as a significant determinant of the state-level soybean supply, it could be assessed that the U.S. would likely benefit by increasing its soybean output not only in larger states, but also in comparatively smaller soybean-producing states.

1.8 Scope of the Study

This study will focus primarily on deriving an empirical supply model for the state-level soybean supply/production in the U.S. using approximately two decades (2000–2019) of annual data on different key identified determinants. With the help of past literature, the economic determinants of state-level soybean supply are first identified, and then data is collected on those variables for each U.S. soybean-producing state. Finally, with the help of statistical tools and methodologies, the significance of those suspect variables is tested, deriving the final state-level soybean supply model.

In addition, this study looks forward to analyzing the elasticity of soybean supply, primarily with respect to the 'Chinese tariff measure', and secondarily to 'world meat consumption' for 28 of the U.S. soybean-producing states. The detailed method of calculating Chinese tariff measure for each U.S. state from China's tariff rate is explained in the methodology section. Adding to the previous studies conducted on specifying U.S. soybean supply model, this study maintains novelty by including the data both before and after the US-China trade war on a state level.

For policy implications, this study will estimate the elasticity of soybean supply with respect to government subsidies and soybean yield, the latter two variables being usually under the control of the government. Through this research, no claim is made that the reader will achieve a comprehensive understanding of the U.S. soybean markets regarding both supply and demand mechanisms of the soybean market. However, this study will help the reader discern an empirical supply model of the U.S. state-level soybean supply, whether that was vulnerable to the Chinese import tariffs, and how responsive it is to its economic determinants.

The study has been organized as follows:

- Section 2 reviews past literature
- Section 4 and 5 discuss the methodological framework and data description, respectively.
- Section 6 and 7 present results and conclusions, respectively.

CHAPTER 2

LITERATURE REVIEW

The U.S. being a major supplier of soybean in the world beginning in the early 50s, a good amount of literature on soybean topic is neatly available from various researchers and journals. Each of these literature reviewed for this study has given us more insight into the U.S. and international soybean market and, more importantly, what key determinants drive the supply of soybean at US national level. This section shows some studies conducted similar to our questions and brief discussions regarding what researchers had found in their empirical studies.

2.1 Studies regarding supply function of US soybean and soybean products

Vandenvorre (1964) modeled for demand function of U.S. soybean oil and U.S. soybean meal using ten simultaneous equation models, finding that the price of soybean oil, price of competing vegetable oil, and supply of butter and lard determines U.S. soybean oil demand. For the U.S. soybean meal demand function, he assessed that it depended upon the price of U.S. soybean meal, supply of other substitute feed, prices of livestock products, and quantity of feed-grain available in that year. For the soybean meal supply function, he found that the soybean meal supply depended on acreage planted of soybeans and average rainfall in the U.S. soy-belt.

Heady and Rao (1967) assessed that soybean to corn price ratio was significant in explaining soybean acreage in Iowa, indicating that corn prices influenced soybean acreage and thus its production.

Houck and Subotnik, (1969) employed a distributed lag estimation model where they exploited data on the price support programs of a competing commodity for corn, i.e., the price support programs of soybean and acreage planted in the estimation of their corn regional acreage response, import demand, and impact multipliers of policy changes for different agricultural regions of the U.S.

Matthews *et al*. (1971) used a simultaneous equation model to assess and report that increase in soybean prices increase soybean acreage and simultaneously decrease corn acreage. Furthermore, they added that depreciation of the dollar in the international foreign exchange rate leads to an increase in soybean price.

In their study, Ash and Meyers (1986) developed a sub-model for Iowa's supply, demand, and price behavioral relationship of soybean, meal, and oil markets from the simultaneous U.S. national model. Their empirical flowchart of the Iowa sub-model depicts Iowa's soybean production as a function of Iowa's soybean yield, Iowa's soybean acreage, Iowa's corn and soybean price, Iowa's soybeans cost of production, and Iowa's corn and soybean net returns. Their model also reveals Iowa's net exports as a determinant of that year's soybean production.

Sarwar (1989) revealed through his research that the soybean prices received by farmers is also dependent upon variable transport costs. In particular, his results show that a higher ocean transport rate will reduce producer prices for U.S. soybean producers.

Soltani (1984) identified the significance of Japan as the largest importer of U.S. soybean during that research period and used multiple regression model analysis to find that Japan's population, Japan's per capita income, price of U.S. soybean, and US-Yen exchange rate were significant in explaining the U.S. soybean export to Japan. Although, he stated that the price of corn, Japanese domestic production of soybeans, Japanese livestock production, and Brazil's soybean production were insignificant at the given statistical significance level.

Shumway and Lim (1993) emphasize the importance of estimates of the elasticity of supply in their research for policy implications. They conducted tests for different functional forms (Translog, Generalized Leontief, and Normalized Quadratic) of the production function of U.S. agricultural commodities, including livestock, fluid milk, grains, oilseeds, and other crops. Their research, however, is not similar to our research question as their focus of the research was on estimating the functional form of a production function, while this study will look into estimating the U.S. state-level soybean supply model.

Baffes *et al*. (1988) using a dynamic framework, studied and reported that the demand and supply for US wheat, corn and soybeans export behave differently. They state that U.S. corn exports are elastic while U.S. soybeans exhibited an inelastic response. Furthermore, they add that soybean export prices respond significantly to domestic export capacity changes but little to external shocks.

Cui (2001) using Simultaneous Equation Model, studied factors affecting soybean prices and found that it was positively affected by time trend variable, expected wholesale price of corn oil, expected real expenditures spent on food, expected variable cost of growing soybeans, and one-year lagged farm-level corn price, but was negatively affected by one-year lagged soybean price, one-year lagged wheat price and one-year lagged acreage of soybeans. The researcher also found that canola oil and soybean oil prices were highly correlated.

2.2 Studies regarding US-China Trade War and impact

Due to the gigantic volume of soybean trade between the U.S. and China, both qualitative and quantitative impacts of retaliatory tariffs on the soybean industry both at the world and U.S. level was studied by many researchers, some of which are succinctly discussed below.

Zheng *et al*. (2018) utilized Global Simulation Model (GSIM) to estimate the short-run quantitative impacts of the Chinese retaliatory tariff on U.S. domestic prices, production, exports, and welfare relative to soybean, including three other agricultural commodities. The researchers increased the average tariff rate for each product by 25 percentage points to run the simulation and found that U.S. domestic soybean prices, production, export, and producer surplus would decline due to the increased tariff rate. The researchers used data on U.S. national production, bilateral tariff rates, and trade elasticities between trading partners. The researchers had predicted that U.S. soybean prices would fall by 3.9%, production would fall by 1.6%, the value of U.S. soybean export to China would decrease by 34.2%, and the producers would face significant losses due to decline in prices and exports in that year.

Taheripour and Tyner, (2018) used the Global Trade Analysis Project-Biofuels (GTAP-BIO) model to estimate medium to long-run quantitative impacts of 25% Chinese import tariff on bilateral imports and exports of soybean, production, prices, and economic welfare of soybeans. Their model utilized the data on standard GTAP trade elasticities and elevated trade elasticities between U.S. and China, along with a 25% increase in Chinese import tariff for U.S. soybean. The researchers concluded that this trade-ware is a lose-lose situation for both U.S. and China, such that U.S. soybean producers and Chinese buyers will have to face a decline in economic welfare.

Adjemian *et al*. (2019) have utilized the Relative Price of a Substitute (RPS) model to estimate the potential impacts of Chinese retaliatory tariffs on U.S. soybean prices. The researchers used data from January 2015 to February 2019 and revealed that the Chinese retaliatory tariff on U.S. soybean disrupted the world soybean market and lowered the U.S. soybean prices by $0.65/bushel for five months in Gulf markets.

Sabala and Devadoss (2018) have used the Spatial Equilibrium Model (SEM) to study and quantify the impacts on price, bilateral trade flow, supply, and demand resulting from 25% Chinese retaliatory tariff on U.S. soybeans. Data used for their research was from 2015 to 2018. They concluded that the Chinese retaliatory tariffs impacted as a net loss for the U.S., China, and Canada. China faces economic losses because of its soybean consumers, the U.S. faces losses because of its soybean producers, and Canada faces economic losses because the U.S. displaces some of its soybean exports to the European Union. In contrast, the researchers concluded that Retaliatory tariffs rewarded Brazil as it has the opportunity to replace U.S. soybeans in the Chinese market. However, it has been found that the world will face loss in economic welfare and incur economic inefficiency.

Bekkers and Schroeter (2020) exploited the World Trade Organization's (WTO) Global Trade Model to examine the medium-run impacts of the tariffs and trade uncertainty and found that global GDP would fall by 0.13% by 2023 due to increased US-China tariffs. According to the researchers, the Phase-One Agreement between U.S. and China that came into effect from January 15, 2020, is expected to have a "very small" impact as it does not address the tariff hikes and does not lessen trade uncertainty. According to the researchers, Chinese tariffs on U.S. exports have increased from 8% to 21.8% and might further increase to 25.9%, whereas U.S. tariffs on imports from China have increased from 3.1% in 2017 to 21% and might increase further to 26.6%. The researchers also conclude that global GDP would fall by 0.13% because of the trade war between the U.S. and China.

Doifode and Narayanan (2020) utilized the Fixed Effect panel model to estimate the value of exports impacted by the US-China trade war in both countries and conclude that consumers, farmers, and manufacturers will be negatively impacted.

Amiti *et al*. (2019) utilized the Fixed Effect model to conclude that aggregate U.S. real income would decline due to imposed retaliatory tariffs.

Morgan *et al*. (2022) used the product-line econometric estimates from Grant *et al*. (2021) and the USDA ERS to assess the impact of retaliatory tariffs on U.S. agricultural exports. The researchers concluded that soybeans bore the most shock of the total trade loss at the commodity level, $9.4 billion of annualized losses, and at the state level, Iowa, Illinois followed by Kansas, were the ones to bear the most losses. They also found that Brazil gained most of the U.S. soybean exports lost to China.

Elobeid *et al*., (2019) used CARD/FAPRI agricultural modeling system and the IMPLAN model to find that the consequences of retaliatory tariffs are trade destruction and trade diversion. The researchers concluded that U.S. exports for soybean could decline by 15%, and the soybean price could fall by 8-12%. According to them, the decline in foreign demand and prices would lead to reduced production in the U.S. agro-industry, eventually leading to reduced welfare and jobs.

U.S. soybean and corn prices were modeled by Ghoshray (2019), where the researcher used monthly cash price data of corn and soybeans from January 1973 to September 2018 using Flexible Fourier estimation procedure, and revealed that corn prices are significant in forecasting soybean prices.

Hao (2019), using data from 2001–2018, modeled the U.S. soybean production using the time series regression model and found that Chinese retaliatory tariffs were significant in explaining the national soybean production. The researcher assessed that soybean production was dependent on the first leg of its explanatory variables. Intuitively, most of the farms in the Mid-west region of the U.S. plant soybean once a year (USDA NASS, 2020). The farms make their production decisions based on data on key determinants from the past season, shown by Hao (2019).

The approaches and the econometric models adapted by respective researchers above have merits in finding answers to their respective research questions. However, the objective here is to identify key determinants for the state-level soybean supply model. Additionally, one of the aims of this study is to find the partial elasticity of the Chinese tariff measure on state-level soybean supply, given that other determinants remain constant. The variable of interest in our context is a policy variable, i.e., China's import tariff measure, and to assess whether it is significant in determining the state-level soybean production of the U.S. In order to meet the study objectives, an empirical method similar to Soltani (1984) and Hao (2019), is adopted along with a method to account for state-level Chinese Tariff Measure from Waugh (2019).

2.3 Identifying Determinants of Soybean Production

The production of an agricultural commodity such as soybean is determined by a number of factors that can be; market price of the commodity, expansion or contraction of crop acreage, increasing or decreasing yield of the crop over time, government support programs, cost of operating farm, price of competing crop, quantity demanded, and/or geo-climatic situation of a region, (Lubowski *et al*., 2008, Huang and Khanna, 2010, Lee *et al*., 2016).

The price of soybean is apparently one of the most significant determinants of soybean production in the US (Vandenvorre, 1964; Heady and Rao 1967; Matthews *et al*., 1971; Ash and Meyers, 1986; Soltani, 1984; Hao, 2019). Furthermore, price of corn also affected soybean acreage in the US (Heady and Rao, 1967; Matthews *et al*., 1971). In the Mid-west region corns are generally cultivated in rotation with the soybean for practicing better crop management (Timmerman *et al*., 2014). It has been found that any drastic deviations in the relative price of soybeans to corn can significantly impact soybean crop acreage (Curran, 2020). Savernini (2009) utilized Vector Autoregression (VAR) Model to investigate the relationships among US corn prices, US ethanol production, US soybean prices and World Oil Prices, and in their conclusion, they argued that lower corn prices would induce farmers to increase production of soybeans, implying that increase in relative price of soybean to corn leads to increase in soybean production.

Lee *et al*., (2016) assessed that global soybean production and trade were significantly influenced by the domestic and foreign trade policies of major importers and exporters. They also argued that the rising demand for meat consumption boosts the demand for livestock feed, the majority of which comes from soybeans. Hansen and Gale (2014) studied that rising meat demand caused the growth of imports for feed in China. Masuda and Goldsmith (2012) assessed China’s livestock demand elasticity for soybean meal at 0.91. From the literature, increasing world meat consumption was assessed to be the driver behind the increased demand for livestock feed (soybean meal). Hence, it could be assumed that world meat consumption is a proxy demand shifter for soybean supply in the world. The U.S. being the major soybean supplier in the world, it could also be assumed that the U.S. soybean supply has more than likely been affected by the increased demand for livestock feed.

Table 2. 1: Explanatory variables and their impacts on Soybean Supply as explained in literature

S.N.	Potential Explanatory Variable	Impact on Soybean Supply as reported in Literature
1.	Soybean Acreage	• Has positive impact on soybean supply (Vandenvorre, 1964; Houck and Subotnik, 1969; Houck *et al.*, 1972)
2.	Soybean Yield	• Positively impacts soybean supply (Ates and Bukowski, 2021)
3.	Soybean to Corn Price Ratio	• Positively impacts soybean supply (Heady and Rao, 1967; Matthews, 1971)
4.	China's Tariff Measures	• Has negative impact upon soybean supply (Zheng et. al., 2018; Elobeid *et al*., 2019; Hao, 2019)
5.	U.S. Government Subsidy for Soybeans	• Has positive impact on soybean production (Houck *et al*., 1972; Giri *et al*., 2018; Ates and Bukowski, 2021)
6.	Cost of Soybean Production	• Has negative impacts on soybean supply (Goldsmith, 2008; Regmi, 2019)
7.	Demand for Meat Consumption (i.e., Demand for soybean)	• Positively impacts soybean supply (Masuda and Goldsmith, 2012; Hansen and Gale, 2014; Lee *et al*., 2016)
8.	Nominal annual exchange rate (Yuan/Dollar)	• Negatively impacts soybean supply (Mathews, 1971; Soltani, 1984; Johnson and Zeng, 2021)

Soybean is a major agricultural commodity of the U.S. exported to different nations and in majority to China (USDA, 2021). Shane *et al.* (2008) assessed that while the long-term growth in U.S. agricultural exports is largely driven by growth in foreign income, year-to-year variation in U.S. agricultural exports was largely driven by changes in exchange rates. It has been observed that when the value of the U.S. Dollar is high relative to a trading partner's currency, the agricultural exports to that trading partner decline, and vice-versa (Johnson and Zeng, 2021). The Yuan-Dollar ratio has been assumed to be a control variable for the variation in the state-level soybean supply which arises from the variation in export of U.S. soybeans to major trading nations such as China. If the Yuan-Dollar ratio increases, the value of the U.S. dollar appreciates relative to Yuan, leading to a decline in soybean exports, on the contrary, if the Yuan-Dollar ratio decreases, the value of the U.S. dollar depreciates relative to Yuan, leading to increased export of soybean to China.

The economic theory and literature suggested that prices received for soybeans was the major determinant for production decision among producers/farmers, as it has direct impact upon the net revenue of the farmers. Along with the former, soybean acreage, soybean yield, relative price of soybean to corn, China's import tariff rates for soybeans, the US's commodity support programs for its soybean producers, domestic as well as international demand for the meat consumption, nominal currency exchange rate between US and China, and cost of production, are the key determinants for soybean production (Vandenvorre, 1964; heady and Rao, 1967, Houck and Subotnik, 1969, Ash and Meyers 1986, Soltani 1984, Zheng *et al*., 2018; and Adjemian, 2021).

From the literature reviewed, it can be deduced that rise in soybean acreage, soybean yield, relative price of soybean to corn, US government's support programs and demand for meat consumption will lead to rise in soybean supply (Vandenvorre, 1964; Goldsmith, 2008, Lee *et al*., 2016, Ates and Bukowski, 2021). In contrast, rise in China's import tariff for soybeans, cost of production, and nominal exchange rate of Yuan to Dollar will lead to decline in the soybean supply from US states.

The above-mentioned explanatory variables in table 2.1 will be analyzed in this study with the hopes to identify the key determinants, and to estimate an empirical supply model for the US state-level soybean.

CHAPTER 3

STUDY OBJECTIVES

While previous studies have examined many aspects of the national soybean market, this study is aimed at identifying the determinants of soybean supply at the state-level by using data from the past two decades (2000-2019). This research study has the following objectives:

i. To identify a state-level measure of trade policies, especially China's import tariffs, which is likely a key determinant of state-level soybean supply.
ii. To estimate a state-level soybean supply model for major soybean producing states, using data available from 2000–2019, to identify its economic determinants.
iii. To compute the response of state-level soybean supply to Chinese import tariffs.
iv. To compute the response of state-level soybean supply to world meat consumption, a proxy for combined domestic and foreign demand.

CHAPTER 4

METHODOLOGICAL FRAMEWORK

4.1 The Hypothesized Model

From the existing literature on U.S. soybean supply, key economic determinants of the national-level soybean supply, and thus state-level soybean supply were deduced; soybean acreage, soybean yield, soybean to corn price ratio, state-level Chinese tariff measure, U.S. government soybean subsidies in each state, cost of soybean production, world meat consumption (a proxy for feed demand, i.e., a shifter), and nominal currency exchange rate (Yuan/Dollar). Mathematically, this relationship can be viewed as follows:

$$Qs_{it}\,(A_{it},\ Y_{it},\ RPs_{it},\ TM_{it},\ GS_{it},\ Cs_{it},\ WM_{t},\ ER_{t}) \qquad (1)$$

where,

Qs_{it} = Quantity supplied/produced in a state *i* in year *t*

A_{it} = Acreage planted for soybean in a state *i* in year *t*

Y_{it} = Yield of soybean in a state *i* in year *t*

RPs_{it} = Soybean to corn price ratio in a state *i* in year *t*

TM_{it} = Chinese tariff measure for a state *i* in year *t*

GS_{it} = Government subsidies for soybean in a state *i* in year *t*

Cs_{it} = Cost of soybean production in a state *i* in year *t*

WM_{t} = World meat consumption in year *t*

ER_t = Nominal annual exchange rate (Yuan/Dollar) in year t

Studies conducted by past researchers revealed that the national level soybean production was estimated via the first lag of each of the determinants above (Vandenvorre, 1964; Houck *et al*., 1972; Hao, 2019). Intuitively, soybean being an annual crop in most of the states of the U.S., state-level soybean supply would be impacted by the information available from past year.

Some literatures hinted that future (expected) soybean prices could possibly impact soybean supply, however, data on future soybean prices could not be retrieved for each state in this study. Moreover, it was suggested that soybean supply was impacted significantly by corn prices in the U.S. During initial statistical analysis, it was revealed that including soybean prices and corn prices as two distinct explanatory variables led to severe multicollinearity. In order to address this, a soybean-corn price ratio variable was utilized. The soybean-corn price ratio is a measure of the price of soybean received by suppliers in each state per dollar price of corn received by the suppliers. In simple words, an increase in the soybean-corn price ratio would incentivize suppliers to supply more soybean, as their net returns would be higher by planting soybean. Additionally, economic theory suggests that quantity of supply lags the change in price of that commodity. Thus, it was hypothesized that soybean-corn price ratio from previous year would impact soybean supply this year.

Literature suggested that the variable world meat consumption largely drove the demand for livestock feed (majority of which comes from soybean), and the U.S. is the major supplier of soybean in the world. Economic theory suggested that a shift in supply lags the shift in demand. In this context, it would be reasonable to assume that any shift in soybean supply this year would be due to the shift in demand from previous year. Thus, world meat consumption being a proxy for the demand of soybean globally, it was hypothesized that world meat consumption from previous year impacted the soybean supplied this year.

Likewise, literature suggested that year-to-year variation in the exchange rates between the U.S. and trading nations largely impacted the amount of agricultural commodities (including soybean) exported by the U.S. to other trading nations (Shane *et al.,* 2008). It was found that besides domestic consumption, exports of soybean drove the supply of soybean in the U.S. The Yuan to Dollar ratio was a control variable for variation in the soybean supply which was due to the variation in soybean exported from U.S. to China. Hence, previous year's Yuan/Dollar ratio was hypothesized to impact soybean supply of this year.

Now, (1) can be rewritten as:

$$Qs_{it}\,(A_{it-1},\ Y_{it-1},\ RPs_{it-1},\ TM_{it-1},\ GS_{it-1},\ Cs_{it-1},\ WM_{t-1},\ ERs_{t-1}) \qquad (2)$$

Here, $t\text{-}1$ for each variable represents first lag of that variable, i.e. data available from previous year. This study hypothesizes that each of the economic determinant in (2) is significant in explaining the state-level soybean supply. In other words, the estimated coefficients of the determinants will be statistically different from zero. The two main variables of interest of this study were Chinese tariff measure, and world meat consumption.

4.2 The Estimated Model

This section discusses the estimation techniques employed in this study to analyze the data and retrieve the results. Since the available data had both cross-sectional and time components, i.e., in the form of panel data, the literature provided three key econometric models; pooled OLS, random effects (RE), and fixed effect (FE) model. Model selection between pooled OLS and RE model was tested by using a lagrange multiplier (LM) test. The null hypothesis of LM test states that no panel effect exists in the data, and rejection of the null will lead to selection of the RE model. Furthermore, model selection between RE and FE model was tested by using Hausman test, the null hypothesis of which states that RE model is relatively more precise estimator of the coefficients.

Soybean production differs across states, mainly due to observables discussed earlier, and partly due to unobserved variables such as differences in weather and climate, transportation, and proximity of oilseed processing plants. However, using the FE model allows for controlling the unobserved variables among states and, in the process, helps in controlling the endogeneity caused due to 'between' variation of the states. Furthermore, the FE model can also account for unobserved variables within a state that, on average, remain constant over time. FE model utilizes the variation within cross-sectional components (i.e., states) of the data to describe a relationship between the soybean supply and determinant variables. For the data to be used in the FE model, a FE transformation could manually conducted (in accordance to Woolridge, 2015, 5th edition) or the in-built '*xtreg fe*' syntax of the STATA program could be exploited to account for this transformation.

After identification of possible determinants of soybean supply as discussed in section 4.1, the next step for estimation was to create and then use a state-weighted Chinese tariff measure. First, the Chinese import tariff on U.S. soybean was adjusted to represent state-level exposure to the retaliatory tariffs. Assessment made, and evidence provided by Waugh (2019) indicated that not all counties were equally exposed to the Chinese retaliatory tariffs. Similar to Waugh (2019), the variation in a U.S. state's exposure to the Chinese retaliatory tariffs from 2000 to 2019 is computed and then considered as a determinant of state-level soybean supply.

Tariff data (from 2000–2019) of Chinese tariff on U.S. soybean were obtained from Inouye and Ward (2020), USDA FAS (2021), and Zheng *et al*. (2019). In other words, a Chinese import tariff rate for U.S. soybean at time t (i.e. Γ_t) was obtained. Then, another ratio was calculated; the number of soybean farms in a given state ($F_{state,t}$) to the total number of soybean farms in the U.S. ($F_{U.S.,t}$), from 2000 to 2019. Since the number of soybean farms in a state changed between this study's given time period of analysis, this variation was accommodated into the state-level China's tariff measure. The number of soybean farms was obtained from the U.S. Census of Agriculture since 1997 – 2017. Since the agricultural census is conducted every five-year, the number of farms in any given state remains unchanged in the data for that interval. For example, the number of soybean farms for Illinois in year 2000 and 2001 were obtained from agricultural census of 1997, likewise, the number of farms for the same state from 2002–2006 were obtained from agricultural census of 2002, and so on. This means that the data on number of farms in Illinois from 2002–2006 are equal, and so on for other states. The original ratio used by Waugh (2019) consists of a county's number of employment in a specific commodity sector '*s*' to the total employment in that commodity sector 'S'. The idea behind using ratio of soybean farms instead of ratio of soybean employment is consistent with the argument of Waugh (2019) that if a state has a larger number of soybean farms, then the exposure to Chinese tariffs will be higher. Another possibility was to utilize the ratio of soybean acreage in each state to the total soybean acreage of the U.S., as a possible weight for the Chinese tariff. However, the latter ratio was not explored in this study, due to the fear of multicollinearity, which was a possibility since the model already included soybean acreage as an explanatory variable. But it could not be stated with certainty whether using the latter ratio would have resulted in multicollinearity, since it was unexplored.

Finally, the following equation yields a state-level Chinese tariff measure for each state:

$$\Gamma_{\text{state, t}} = \sum_{state \in US} \frac{F_{state,t}}{F_{US,t}} \Gamma_t$$

Using above equation, the variable of interest, Chinese import tariff was transformed into Chinese tariff measure for individual states, which accounts for the exposure measure of Chinese tariff for each soybean producing states in this study.

Initial analysis of candidate models was carried out as level-level model, log-level model, level-log model, and log-log model, whereby all of the determinant (explanatory) variables had been treated with a first lag operator, and where needed, a natural log transformation of the dependent and the determinants had been performed.

In order to analyze if any of the candidate models had omitted variable bias and incorrect misspecification of the functional form, Ramsey's RESET test was conducted. The log-log model was specified through failure to reject the null hypothesis of the test, which states that the candidate model was void of omitted variable bias and had correct functional form. Moreover, the signs of estimated coefficients of the determinants were also found to be consistent with that implied in the literature.

After specifying the log-log functional form of the soybean supply model, separate tests for autocorrelation, endogeneity, and heteroskedasticity were conducted. Autocorrelation was tested using the tests suggested by Wursten (2016). In case autocorrelation was present, a method suggested by Woolridge (2017) to cluster the states was adapted to mitigate autocorrelation. Endogeneity was tested for the model using the method provided by

Woolridge (2017). In case endogeneity was present, two possible instrument variables; U.S. income per capita and corn supply would be used. Robust standard errors were obtained to address heteroskedasticity and autocorrelation by clustering the individual states, a method referred from Woolridge (2017).

CHAPTER 5

DATA

Data were collected in accordance to the literature on key variables that were identified to be determinants of the soybean supply. Data were retrieved from various government sources such as USDA Foreign Agricultural Services (FAS), USDA Farmers Service Agency (FSA), and USDA National Agricultural Statistics and Services (NASS), USDA Economic Research Service (ERS), and other non-governmental sources such as American Soybean Association (ASA), Food and Agricultural Organization (FAO) database, Environmental Working Group (EWG) subsidies database, and Organization for Economic Co-operation and Development (OECD) database.

With the intention to study every soybean producing states in the U.S., data were retrieved for 28 soybean-producing states as reported in ASA's 2019 annual report (ASA, 2019). The annual state-level data for different variables were retrieved for the 28 soybean producing states of the U.S. from 2000 to 2019. The name of these states are listed in alphabetical order in the Appendix 1 section.

'Soybean supply (Qs)', which was this study's dependent variable, was the annual state-level soybean produced in a given state. The unit of measurement for Qs was 'million bushels'. Soybean supply for each state was obtained from USDA NASS quickstats which is freely accessible to the public. Initially the data was available in thousands of bushels, which was converted into millions of bushels using conversion factor provided by USDA ERS

Table 5. 1: Summary Statistics of the Data

Variable	Symbol	Unit	No. of Obs.	Mean	Std. Dev.	Min.	Max.
Soybean supply	Qs	million bushels	560	118.6119	137.3554	2.208	666.8
Acreage planted	X1	million acres	560	2.755745	2.818608	0.082	11
Yield of soybean	X2	bushels per acre	560	39.45668	9.285886	13	88.74
Relative Price of Soy–Corn	X3	–	560	2.385564	0.3189012	1.657534	3.171355
Chinese Tariff Measure	(1+X4)	–	560	1.195726	0.4343094	1.005632	4.741509
Subsidies for soybeans	X5	$ in million	560	65.06324	85.709	0.906455	756.3932
Soybean production cost	X6	$ per planted acre	560	336.0441	93.55306	176.87	563.98
World meat consumption	X7	thousand metric ton	560	281122.2	33102.53	227097.3	328478.5
Nominal exchange rate (Yuan/Dollar)	X8	–	560	7.199017	0.8154139	6.143	8.278417

(1992). The Mid-western region of the U.S. had one of the highest amount of soybean production in the U.S., whereas states such as Delaware, Georgia, New Jersey and Alabama had significantly lower amount of soybean supply. Table 5.1 illustrates that the dependent variable has std. dev. higher than its mean, implying that lower soybean producing states supply only a fraction of what the Mid-western states supply.

A brief description about the data characteristics of explanatory variables of this study is provided below. ‘Soybean acreage (X1)’, and ‘Soybean yield (X2)’ were the annual state-level data for acreage planted, and yield of soybean, respectively, in the 28 U.S. states. 'Soybean acreage (X1)' was measured in million acres, and 'Soybean yield (X2)' was measured in bushel per acre. These data were retrieved from USDA NASS quickstats. It was observed in the literature that both of these variables had positive impact on the soybean supply.

'Soybean to corn price ratio (X3)' was the ratio of state-level soybean prices to the state-level corn prices. Thus, being a ratio, it did not have a unit of measurement. Separate data were obtained for the state-level price of soybean and state-level price of corn, and then a simple ratio was taken to achieve X3. This ratio signaled the farmers' production decision between producing soybean and corn. Literature suggested that an increase in X3 would lead to an increase in soybean supply. From table 5.1, it can be observed that the average annual relative price ratio in all states is 2.385, which meant that, on average, farmers received 2.385 times more price from the equal quantity of soybean than that of corn. Intuitively, if this ratio went up, farmers were more incentivized towards producing soybean than corn, and vice versa.

'State-level Chinese tariff measure (X4)' is one of the variable of interest for this study. Using Waugh's (2019) method to calculate the county-level tariff measure, as discussed in section 4.2, this study calculated the state-level Chinese tariff measure for each state from 2000 to 2019. The Chinese tariff measure was symbolized by X4, which lied between 0 and 4 for different states, i.e., $0 < X4 < 4$. However, with the technique illustrated by Waugh (2019), X4 was modified in order to accommodate log transformation by adding each value of X4 for each state i in year t with one, i.e., the coefficient of $\log(1 + X4)$ was the coefficient of interest. The original data on applied MFN tariff rates was obtained from Inouye and Ward (2020), and also referenced from Zheng *et al*. (2019).

'U.S. government soybean subsidies (X5)' included annual government payments made to the soybean farmers in each state from 2000 to 2019, under contemporaneous soybean support programs. The source of this data was EWG (2020). The subsidies data varied depending upon the amount of soybean supplied by a state. If a state had a larger supply of soybeans, it was observed to have received higher government payments in comparison to states that supply less soybean. As revealed in the literature that MFP payments had no statistically significant impact upon the production decisions of the U.S. soybean farmers (Giri *et al*., 2018; Janzen and Hendricks, 2020; Swearingen and Janzen, 2021; USDA ERS a, 2021; Morgan *et al*., 2022), an assumption is made in this study that MFP payments had no impact on soybean production, hence it was excluded.

'Soybean production cost (X6)' was retrieved from the USDA ERS website. This annual data for soybean production cost (measured in bushel per acre) was attributed to each U.S. Farm Resource Region, as defined by the USDA ERS (2000). Observing figure 5.1, those regions could be better understood with respect to each soybean-producing state. Through the USDA ERS's description of U.S. farm resource regions on their website, states were allocated into farm resource regions, and their corresponding average annual soybean production costs were assigned. This means that two or more states in the same U.S. Farm Resource Region had similar production costs. The USDA ERS argues that these regions had been formulated in 2000, as areas depicting geographies specialized in producing specific U.S. farm commodities. So, it seemed plausible that any two or more states could have a similar cost of production, given that the factors of production remain relatively similar.

Soybean production cost covered operating costs (seed, fertilizer, chemicals, custom services, fuel, lube, electricity, repairs, purchased irrigation water, and interest on operating capital), and other costs such as hired labor costs, the opportunity cost of unpaid labor, capital recovery of machinery and equipment, the opportunity cost of land, taxes, and insurance, and general farm overhead cost (USDA ERS, 2021). The Heartland region was observed to have the lowest production cost for soybeans.

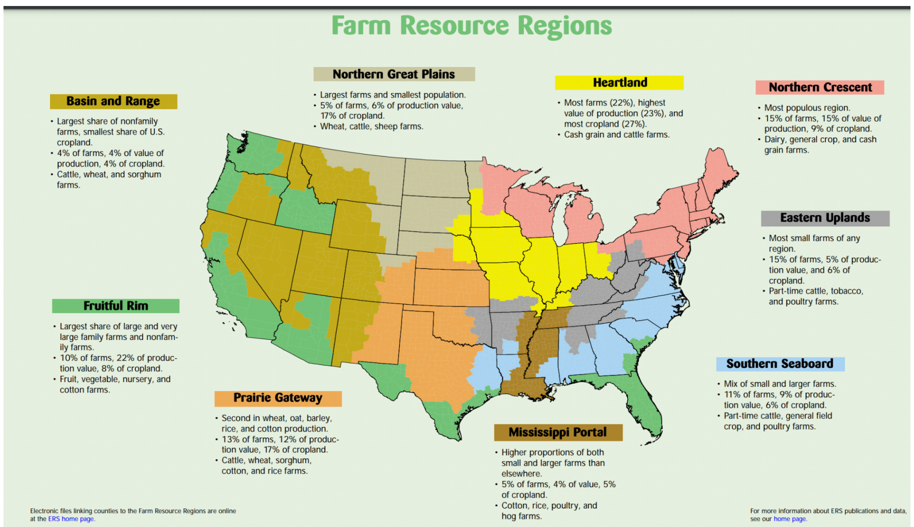

Figure 5. 1: US Farm Resource Region (USDA ERS, 2000, p.2)

The second variable of interest of this study, 'world meat consumption (X7)' was obtained from OECD database, which was annual data on meat consumption for the entire world from 2000–2019, and was measured in thousand metric tons. It was summation of total meat consumed of beef and veal, poultry, goat, and sheep across the entire world. Since this data does not have individual components as other state-level data, X7 differs only for the time component for each state, implying that X7 for any two states in a given time *t* will be equal. World meat consumption is assumed to be a proxy explanatory variable, because soybean meals are consumed by livestock, which are in turn consumed by humans. Although there are some literatures that cite meat consumption as one of the reasons for increase in soybean supply, to the author's knowledge, no previous empirical estimation study has estimated meat consumption as an explanatory variable for soybean production/supply. A close study was conducted by Houck *et al*. (1972), who estimated ratio of livestock-feed to livestock unit as a significant determinant of U.S. export of soybean meal. Soltani (1984), following Houck *et al*.'s (1972) study, estimated Japan's livestock production as an explanatory variable for the export of U.S. soybeans to Japan.

'Nominal annual country exchange rate; Yuan/Dollar ratio (X8)' data was obtained from the USDA ERS database. This was a ratio of the nominal value of the Chinese Yuan to the nominal value of U.S. Dollars (USD). It was suggested in past literature that U.S. soybean supply was impacted by both domestic consumption and by export to different trading nations. Year-to-year variation in currency exchange ratio between trading nations and the U.S. were found to impact the export of U.S. soybean to trading partners. This study included Yuan-Dollar ratio as a control for the variation in soybean supply due to variation in soybean exported to trading nations. Similar to X7, X8 differs only for the time component for each state, and it was be equal for any two states in a given time *t*.

'U.S. per capita income (X9)' was the annual data on average per capita income for the entire the U.S. from 2000–2019. Its unit is in thousand USD. This data was retrieved from the FRED database (FRED, 2022). Similar to X7 and X8, this data only varied for any two states for the time component. 'Supply/production of corn (X10)' was the data on total corn supplied by an individual state in any given time, measured in million bushels. This data was collected from USDA NASS, and it varied for each state over time. The only purpose of obtaining data for X9 and X10 was to maintain them as possible instrument variables for IV regression, if endogeneity was detected in the estimated model.

CHAPTER 6

RESULTS AND DISCUSSION

Results reported below after statistical analysis of the data provided answers to the following questions: (i) what were the key economic determinants of U.S. state-level soybean supply from 2000–2019? (ii) does the estimated coefficient of Chinese tariff measure hold any empirical significance for explaining the variation in U.S. state-level soybean supply from 2000–2019? (iii) what was the elasticity of U.S. state-level soybean supply to Chinese import tariff measure and to other economic determinants? (iv) on average, did the world meat consumption, a proxy for domestic and foreign demand, significantly impact the U.S.'s state-level soybean supply, in the period of study?

Given the panel nature of the data, tests were conducted to identify the correct panel model for estimation of coefficients. A LM test was conducted to select between pooled OLS and RE model, which resulted in the rejection of the null hypothesis, signaling selection of RE model. The p-value of the LM test was highly significant at the level of five percent. This meant that pooled OLS model was incapable of capturing the panel effect of the data.

A second test, Hausman test was conducted to compare between RE and FE model. The p-value of Hausman test was statistically significant at the level of 5%, indicating rejection of the null hypothesis that RE model was more precise estimator of the coefficients.

Since it became known that the FE was the most suitable among available panel models, four candidate FE model with functional forms as '*log-log*', '*log-level*', '*level-log*' and '*level-level'* were tested using Ramsey's RESET test, in accordance within Woolridge (5^{th}

edition). The test resulted in p-value of 0.3743 for the *log-log* candidate model, which is statistically indifferent from zero, implying failure to reject the null that the estimated model was correctly specified and additionally, and it had no omitted variable bias. This study therefore concluded that *log-log* FE model not only had coefficients that were consistent in sign, but the estimated model specification was also correct by failing to reject the null hypothesis of Ramsey's RESET test. Table 6.1 below is a representation of the results that were estimated using the FE model in the STATA program. Further tests for autocorrelation, endogeneity, and heteroskedasticity were conducted.

Test for autocorrelation was conducted in accordance with Wursten's (2016, and 2018) method, who built syntaxes for conducting FE autocorrelation test in STATA; '*xtistest*', and '*xthrtest*' were the two syntaxes used respectively to find auto-correlation up to order 'p' and to find first-order auto-correlation. The null hypotheses of both tests, respectively, state that the estimated model had no autocorrelation up to order 'p', and had no first-order autocorrelation. Both tests resulted in p-values higher than 0.05, which resulted in failure to reject the null hypothesis at the level of five percent. Thus, these two tests failed to reject the null hypothesis signaling that our estimated model was significantly void of autocorrelation up to order *p,* and also void of first order autocorrelation. Furthermore, Woolridge (2017) assesses that using *xtreg, fe vce(cluster id)* syntax in STATA to cluster the states, gives robust standard errors for both autocorrelation and heteroskedasticity in the FE model.

The correlation matrix (available in Appendix section), showed that the residual of *log-log* FE model was highly correlated with 'soybean acreage (X1)' and 'soybean subsidies (X5)' variables. Endogeneity test was conducted on these two suspect explanatory variables in accordance with Woolridge (2017), however, the null of exogeneity was not rejected for both

Table 6. 1: Estimates from *log-log* FE model. Dependent Variable: State Soybean Supply

Independent Variables	Coefficient	t	P > | t |	95% conf. interval	
log($X1_{it-1}$)	**0.4932945**	5.5	0.000***	0.3094127	0.6771763
	(0.0896184)				
log($X2_{it-1}$)	**0.1757688**	2.06	0.049**	0.0009722	0.3505654
	(0.0851906)				
log($X3_{it-1}$)	**0.5290515**	8.1	0.000***	0.3949621	0.663148
	(0.653511)				
log(1 + $X4_{it-1}$)	**-0.1209011**	-1.91	0.066*	-	0.0087673
	(0.0631964)			0.2505695	
log($X5_{it-1}$)	**0.0863617**	3.26	0.003***	0.0320202	0.1407032
	(0.0264844)				
log($X6_{it-1}$)	**-0.398899**	-3.17	0.004***	-	-
	(0.125667)			0.6567459	0.1410522
log($X7_{it-1}$)	**1.044478**	4.7	0.000***	0.5880364	1.500919
	(0.2224556)				
log($X8_{it-1}$)	**-0.9171907**	-2.98	0.006***	-1.54956	-
	(0.3081976)				0.2848213
_cons	**-6.56137**	-2.08	0.048***	-13.0483	-
	(3.161535)				0.0744361
R^2 (within)	0.5696	R^2 (between)	0.9855		
R^2 (overall)	0.9523				
No. of Observation	532		F(8,27)	188.56	
No. of Groups	28		Prob > F	0.0000	
sigma_u	0.67031151				
sigma_e	0.20705252				
rho	0.91289767				

variables, since the p-value from both tests were higher than the p-value of 0.05, implying that the suspected variables were significantly exogenous at the level of five percent. The endogeneity test was conducted by using X9 and X10 variables as two potential instrumental variables.

Homoscedasticity assumption was maintained by implementing the technique suggested by Woolridge (2017), i.e. by clustering the soybean supplying states. Normality assumption of the error term is maintained by following Central Limit Theorem which states "*The sampling distribution of the sample means approaches a normal distribution as the sample size gets larger – no matter what the shape of the population distribution*."

The final estimated *log-log* FE model of the state-level soybean supply is given below:

$$
\begin{array}{lllll}
\widehat{\log(\boldsymbol{Qs})} = & -6.56137 \quad + & 0.493*\log(X1_{it-1}) + & 0.175*\log(X2_{it-1}) + & 0.529*\log(X3_{it-1}) \\
 & (3.161535) & (0.0896184) & (0.0851906) & (0.653511) \\
 & -0.1209*\log(1 + X4_{it-1}) & +0.086*\log(X5_{it-1}) & -0.398*\log(X6_{it-1}) & +1.044*\log(X7_{it-1}) \\
 & (0.0631964) & (0.0264844) & (0.125667) & (0.2224556) \\
 & -0.917*\log(X8_{it-1}) & & & \\
 & (0.3081976) & & & \\
 & N = 532 & R\text{-squared} = 0.5696 & &
\end{array}
$$

The numbers in the parentheses underneath every coefficient represents the corresponding standard-error estimate.

6.1 Discussion of Results

This study had predetermined objectives with primary focus on estimating an empirical state-level soybean supply model. The primary variables of interests were exposure to China's tariff and world meat consumption, which were hypothesized to be significant determinants of state-level soybean supply in the United States. All the estimated coefficients of rest of the economic determinants were also hypothesized to be statistically significant in explaining the state-level soybean supply. From table 6.1, it is observed that all the coefficients of economic determinants of state-level soybean supply model have the theoretically consistent sign, and all of them are statistically significant at the 5% level, except for the exposure to Chinese tariff measure, which is significant at the 10% level. Since the model specified is a *log-log* model, the estimated coefficients of the model readily depicted elasticity of the soybean supply with respect to each of the corresponding explanatory variables.

The estimated coefficients of soybean acreage ($\log(X1_{it-1})$), and soybean yield ($\log(X2_{it-1})$) are consistent with that suggested in the literature that soybean supply increases with increase in soybean acreage (Vandenvorre, 1964; Heady and Rao, 1967; Houck and Subotnik, 1969; Houck *et al*., 1972; Ash and Meyers, 1986). Vandenvorre (1964) reported that one percent increase in soybean acreage increases soybean meal output by 0.83 percent. Assuming that soybean meal output is directly proportional to soybean supply, the study of this finding is consistent. However, nominal comparison of elasticity between the former and this study wasn't ideal. This was mainly because, this study's dependent variable is state soybean production, and not soybean meal supply. The coefficient estimate of the soybean acreage from this study signaled that, one percent increase in soybean acreage in a given state this year, results in 0.49% increase in that state's soybean supply the next year, on average, and every other variable being constant. This means that soybean supply is relatively inelastic to change in soybean acreage.

The estimated coefficient of soybean yield ($\log(X2_{it-1})$) was statistically significant at the 5% level and had a positive sign as in Ash and Meyers (1986), and Ates and Bukowski (2021). Increase in yield of soybean is a consequence of extensive genetic, pathological, and entomological research, i.e. technological advancement. As economic theory suggested that improvement in technology leads to increase in production, similarly, improvement in the soybean yield over the years led to increase in soybean production. This study found, every other variable being constant, if the soybean yield increased by one percent this year, the state soybean supply will increase by 0.175% next year, on average. Practically, this could possibly mean that the state-level soybean supply is on average comparatively inelastic to any change in soybean yield.

Similar to what was suggested by Heady and Rao (1967), and Ash and Meyers (1986), the estimated coefficient of soybean to corn price ratio ($\log(X3_{it-1})$) is consistent in sign, and statistically significant at the 5 percent level. It is known that soybean and corn are considered complement crops in the U.S. Mid-western region (Soltani, 1984; Goldsmith, 2008), and because of this historical relationship between these two crops, soybean supply has been predicted by using corn price in the several studies (Hao, 2019; Ghoshray, 2019). Ash and Meyers (1986) assessed that increase in corn price will gradually move soybean farmers towards producing corn, which in the long-run will increase price of soybean due to lower supply. This study finds that on average, if everything else remain constant, one percentage increase in the soybean to corn price ratio this year, increases the state soybean supply by almost 0.53% for the next year.

While the estimated coefficients of other hypothesized variables including that of world meat consumption, were found to be statistically significant at the 5% level, the estimated coefficient of Chinese tariff measure ($\log(1 + X4_{it-1})$) was found to significant at the 10% level. This study finds that, on average, if the state-level Chinese tariff measure increases by 1% this year, then the state-level soybean supply will decrease by 0.12% next year, everything else being constant. The sign of the variable is consistent with that assessed by Zheng *et al*., 2018, Elobeid *et al*., 2019, and Adjemian *et al*., 2019. Zheng *et al*. (2018) using Global Simulation Model predicted that U.S. domestic production would fall by 1.6% in the short-run, however, this study's estimate is lower than that. A possible explanation could be the study conducted by Giri *et al.* (2018), where the researchers argued that a decline in price of soybean, which is a major determinant of soybean production, was almost certain due to the record harvest of soybean in 2018, and that decline could have been partly affected by retaliatory Chinese tariffs. Intuitively, it was known that decrease in the price of soybean from previous year would lead to decrease in soybean production this year. It could not be stated with certainty but this study agrees that argument made by Giri *et al*. (2018) could hold empirical significance, that decline in price could have been the major determinant for decline in soybean production in 2019.

The estimated coefficient of government soybean subsidies ($\log(X5_{it-1})$) was consistent with that suggested by Houck and Subotnik (1969), Giri *et al* (2018), and Ates and Bukowski (2021). Houck and Subotnik (1969) estimated that the regional and national harvested soybean acreage, which is a significant determinant of the soybean production, decreased on a different annual rate, when the soybean price support program was decreased at the rate of $0.30/bushel from 1969 to 1973. This study found that, on average, if the government subsidies to soybean farmers in each state increases by 1%, then the soybean production will increase by 0.08%, with everything else being constant. This determinant has significant policy implications for the federal and state-level policy makers.

The coefficient of soybean production cost (log($X6_{it-1}$)) shows the expected sign as suggested by the economic theory of production. Goldsmith (2008), and Regmi (2019) discussed in their study about the negative impact of coefficient of soybean production cost on farmers' profitability, implying that higher production cost would alter farmers' planting decision in the long-run, hence, decreasing soybean supply. This study finds that, on average, everything else being constant, if soybean production cost increases by 1%, then state soybean supply will decrease by 0.39%.

Lee *et al*., (2016) assess that global soybean production and trade is significantly influenced by the domestic and foreign trade policies of major importers and exporters. They argue that the rising demand for meat consumption boosts the demand for livestock feed, majority of which comes from soybeans. Hansen and Gale (2014) studied that rising meat demand is causing growth of imports for feed in China. The second variable of interest of this study was the world meat consumption (log($X7_{it-1}$)). The estimated coefficient of world meat consumption is observed to be consistent with the literature as deduced from the study of Houck (1972), Soltani (1984), Goldsmith (2008), Masuda and Goldsmith (2012), Hansen and Gale (2014) and Lee *et al*. (2016). It could be said, on average, if the world meat consumption increases by 1% this year, the U.S. soybean supply would increase by 1.04% the following year. Since the estimated model was a log-log model, the coefficients readily measure elasticity, and this study finds that state level soybean production has significant elastic response to the world meat consumption. This is comparable to the finding of Masuda and

Goldsmith (2012) who assessed that China's livestock demand elasticity for soybean meal was 0.91.

The estimated coefficient of the nominal currency exchange rate ($\log(X8_{it-1})$) is found to be consistent with the literature. Soltani (1984) found that U.S. soybean prices in Yen were statistically significant, and negatively impacted the U.S. soybean export to Japan. This study finds that the appreciation of the U.S. dollar relative to Chinese Yuan ($\log(X8_{it-1})$) negatively impacted the U.S. soybean production. On average, a percentage decrease in Yuan/Dollar ratio this year, would increase U.S. soybean supply next year by 0.91%, i.e. if the dollar depreciates, U.S. soybean supply would increase. This study also bolsters the argument that the growth of U.S. soybean production relies heavily on foreign exports. Whenever the value of USD depreciates, i.e., the Yuan–Dollar ratio goes down, the agricultural commodities produced in the U.S. becomes cheaper for consumers in foreign nations, hence, leading to increased US exports — increased US supply. On the other hand, whenever, the USD appreciates, i.e. the Yuan-Dollar ratio goes up, US-produced commodities become relatively expensive for foreign consumers, leading to decreased US exports — decreased supply.

CHAPTER 7

SUMMARY AND CONCLUSION

Using previous literature, eight key economic determinants of the state-level soybean supply were identified; state soybean acreage, state soybean yield, state soybean-corn price ratio, Chinese import tariff, state-level government soybean subsidies, state soybean production cost, world meat consumption, and nominal exchange rate (Yuan/USD). While data on most determinants were readily available publicly, the state-level exposure to Chinese tariff required additional computations. Using an advanced method from Waugh (2019), the Chinese tariffs and a state's share of total (U.S.) soybean farms are employed to derive state-level exposure to this trade policy.

Data on the identified determinants were obtained for 28 soybean producing states, for a time period of 2000 to 2019. The beginning of time was selected from 2000, because of the fact that after China joined WTO in January 2001, the trade ports of China were officially open to the world, and the U.S. soybean export to China has seen significant increase since then.

Along with identifying key economic determinants of state-level soybean supply, this study estimated the effects of Chinese tariffs on individual states engaged in soybean production. From previous national-level studies, it could be assumed that major soybean-producing states of the U.S., i.e. the Mid-western states, were the most impacted ones. However, this study found that even the smaller soybean-producing states along with the larger ones, were significantly impacted by the Chinese tariffs, on average.

Each of the above studied eight economic determinants were hypothesized to have statistical significance in explaining the state soybean supply, however this study's variables of interest were, (i) exposure to China's tariff, and (ii) world meat consumption. All the coefficients of the hypothesized economic determinants, (except Chinese tariff measure) were found to be theoretically consistent and statistically significant at the 5% level. A high R-square further confirmed that the economic determinants accounted for a significant share of the variation in state-level soybean supply.

The primary focus of study, the Chinese tariff measure was however found to be significant, at the 10% level. This could be due to limitations regarding the data, which end in 2019. It indicated that if the state-level Chinese tariff measure increased by 1% this year, then the state-level soybean supply will decrease on average by 0.12% next year, everything else being constant. Another limitation regarding this study could possibly be that it does not identify which individual farmer in an individual state was most impacted by Chinese tariffs, or, which individual state was most impacted in comparison to other states. This study could possibly be improved to estimate the differences in supply response for Mid-western (larger) soybean-producing states in comparison to a smaller soybean-producing state using dummy variables for those states.

The coefficient of this study's second variable of interest, world meat consumption was found to be statistically significant at the level of 1%, rejecting the null hypothesis of being statistically indifferent from zero. The state soybean supply is found to be elastic to world meat consumption, a result consistent with the studies reviewed earlier. Despite this study established world meat consumption as a proxy demand shifter for livestock feed (majority of which comes from soybean), through a pragmatic viewpoint of the individual farmer, this variable could be of less significance for determining his/her farm's production decisions. The soybean price variable is generally assumed to be the most significant determinant variable for devising production plans for an individual farm. However, to mitigate multicollinearity between soybean price and corn price, a ratio of those two variables was used instead in this study.

Summarizing the answers to the four questions this study faced earlier:

(i) What were the key economic determinants of U.S. state-level soybean supply from 2000–2019?

The economic determinants of state-level soybean supply for this year are; soybean acreage from last year, soybean yield from last year, soybean-corn price ratio from last year, Chinese tariff measure, government soybean subsidies, soybean production cost from last year, world meat consumption from last year, and nominal Yuan/Dollar exchange rate from last year.

(ii) Did the estimated coefficient on exposure to Chinese tariff measure explain the variation in U.S. state-level soybean supply from 2000–2019? What was the elasticity of U.S. state-level soybean supply to Chinese import tariff measure?

The coefficient of Chinese tariff measure was found consistent to have the right sign, but was statistically significant at the 10% level only. So, state-level soybean supply was relatively inelastic (-0.12%) to exposure to Chinese tariff, but additional data are likely needed to confirm this result.

(iii) On average, did the world meat consumption, a proxy for domestic and foreign demand, significantly impact the U.S.'s state-level soybean supply, in the period of study?

Yes, the world meat consumption variable has a positive sign and is highly significant in explaining the variation in soybean supply at level of 5%.

From the policy implication viewpoint, some of the variables of interest of this study, can be outside of scope of government's actions; Chinese import tariff is controlled by China, and the world meat consumption is driven by growing per capita income, and shift in diet towards meat, especially in developing nations. However, better negotiations with China and supporting stable global growth can be achieved with U.S. leadership. Some other variables in this study have direct policy implications; government subsidies and soybean yield. By modifying soybean support programs, the government can encourage or discourage soybean production. Given that global meat consumption, thus demand for livestock feed is projected to increase in coming years, the U.S. government could implement state-level policies such as better regional research programs for high-yielding soybean varieties, to encourage farmers to increase the output of soybean.

For future studies, researcher could possibly utilize soybean acreage ratio of state-to-national as weights for computation of state-level Chinese tariff measure, in case, multicollinearity is absent. Researchers can also consider simultaneous supply and demand functions for soybean, but that would require improved data on consumption at the state-level as well as in foreign markets.

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APPENDICES

Appendix 1: List of U.S. States Studied

S.N.	Name of the State	S.N.	Name of the State
1.	Alabama	2.	Arkansas
3.	Delaware	4.	Georgia
5.	Illinois	6.	Indiana
7.	Iowa	8.	Kansas
9.	Kentucky	10.	Louisiana
11.	Maryland	12.	Michigan
13.	Minnesota	14.	Mississippi
15.	Missouri	16.	Nebraska
17.	New Jersey	18.	New York
19.	North Carolina	20.	North Dakota
21.	Ohio	22.	Oklahoma
23.	Pennsylvania	24.	South Carolina
25.	South Dakota	26.	Tennessee
27.	Virginia	28.	Wisconsin

Appendix 2: p-values of the statistical tests involved

S.N.	Statistical Test	H_0	p-value
1.	LM Test	No panel effect	0.0000
2.	Hausman Test	RE is the consistent estimator	0.0001
3.	Ramsey's RESET test	No omitted variables	0.3743
4.	Autocorrelation	No serial correlation up to order *p*	0.080
5.	Autocorrelation	No first-order serial correlation	0.083
6.	Endogeneity test on soybean acreage	No Endogeneity	0.359
7.	Endogeneity test on soybean subsidies	No Endogeneity	0.118

Observing the p-values from the autocorrelation test, we would fail to reject the null at the level of 5%, however, the null of no serial correlation would be rejected at the level of 10%. Hence, a method suggested by Woolridge (2017) was adapted to cluster the individual states to obtain standard errors which were robust to both heteroskedasticity and autocorrelation.

Appendix 3: Graphical Representation of Soybean Production Costs in US Heartland

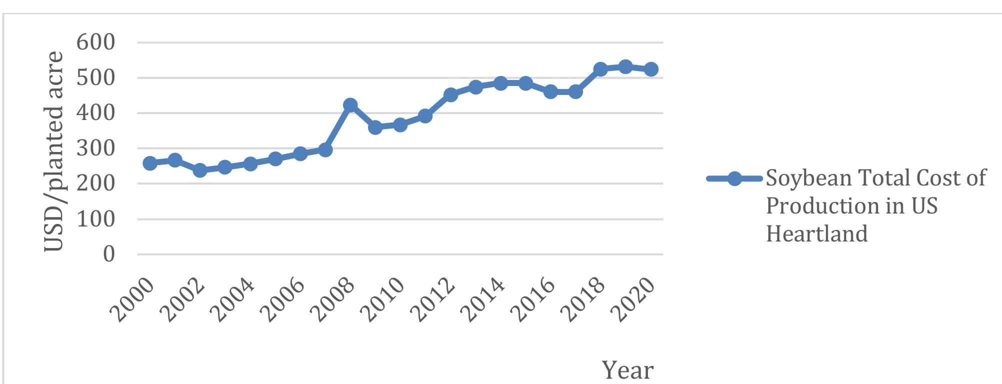

Figure: Soybean Total Cost of Production in US Heartland (USDA ERS, 2021)

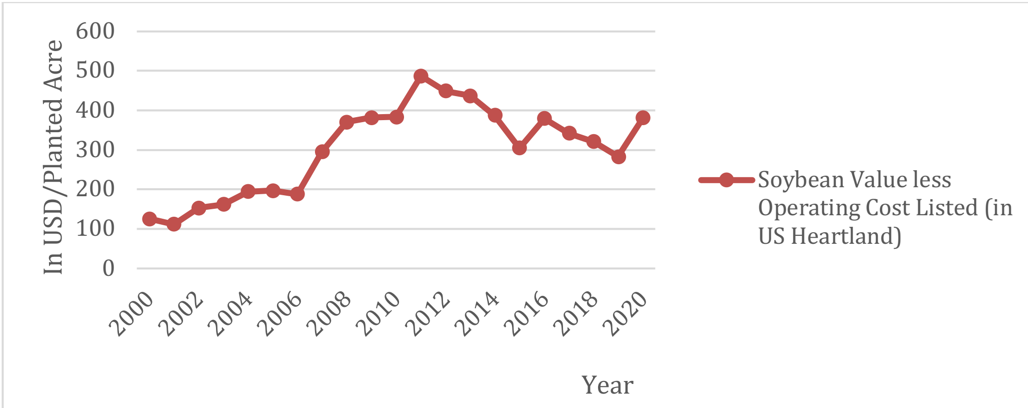

Figure: Soybean Value less Operating Costs in US Heartland (USDA ERS, 2021)

Appendix 4: Correlation Matrix

Correlation matrix of the residual and the independent variables in the log-log model

	Residual								
Residual	1.0000								
X1	0.9181	1.0000							
X2	0.4815	0.4094	1.0000						
X3	0.2781	0.3208	0.1848	1.0000					
X4	0.5383	0.5508	0.3899	0.0909	1.0000				
X5	0.8758	0.9593	0.3951	0.2667	0.5082	1.0000			
X6	0.1544	0.1782	0.5175	0.0221	0.3005	0.2045	1.0000		
X7	-0.0000	0.0687	0.4180	0.0504	0.2080	0.0538	0.8856	1.0000	
X8	0.0000	-0.0643	-0.3555	0.0276	-0.1009	-0.0866	-0.8882	-0.9104	1.0000