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China's Import Tariffs on U.S. Soybean Exports 2018-2022: Effects on Information Transfer between Markets in China, the U.S. and Brazil[1]

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To assess the information transfer relationships, we use vector autoregressive model to generate pairwise tests on the causal covariate differences between the U.S., China, and Brazilian soybean futures prices before and after mid-2008. Results show that previous patterns of price signaling between the U.S. close and China open, and the China close and U.S. open, have all but evaporated since the import tariffs imposed on U.S. exports to China in mid-2008, and recovered only by September 2020. We show, with no ambiguity that where complementary, and causal, price signals between the U.S. and China exchanges were strong and significant at the 1 percent level prior to the tariff, signaling lost all significance up to the 10 percent level thereafter. In contrast, the China close and Brazil open have strengthened throughout the time period with price signalling from China to Brazil became significant at the 1 percent level after the tariffs were imposed and also significant from Brazil to China. This import tariff provided a natural experiment on the effects of a tariff on price information transfers between different markets worldwide as global trade patterns in soybeans changed. We also consider the signaling effect between U.S. soybean futures price and the spot price in China.

[1] Harry de Gorter acknowledges financial support from Operational Program – Integrated Infrastructure, Project No. Drive4SIFood 313011V336 – Demand Driven Research for the Sustainable and Innovative Food, co-financed by the European Regional Development Fund.

Cornell SC Johnson College of Business

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Key words: China, import tariff, soybeans, Brazil, price signaling, futures prices.

JEL: Q14, Q17

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1. Introduction

This paper investigates the impacts of China's import tariff on U.S. soybean exports from mid-2018 on price diffusion and information transfer relationships between prices of soybean futures contracts traded on the Chicago Mercantile Exchange (CME)[2] and the prices of corresponding soybean futures contracts traded on the Dalian Futures Exchange (DCE) in Liaoning China and the CME Brazilian futures contract (B3). The implication of lower diffusion and information transfer relationships in futures prices is that the demand for U.S. soybeans is lower, reducing U.S. cash prices. The U.S. objectives in initiating the overall trade war with China were to cut trade deficits, protect intellectual property of U.S. high-tech industries and bring about moral suasion with China at the negotiating table on trade protocols in general (Liu and Woo, 2018). In response to these U.S. tariffs, China retaliated with import tariffs on a broad swath of U.S. agricultural commodities including a 25 percent import tariff on U.S. soybeans as well as on cotton, sorghum, and pork imports (Zheng et al., 2018), and ultimately an embargo on U.S. soybean imports in October and November 2018. With soybean farmers in both countries losing as did China's soybean processors from the import tariff on U.S. soybean exports, other global soybean suppliers like Brazil and Argentina benefited significantly as they received price premiums over U.S. prices for six months June to November 2018 – see Figure 1.[3]

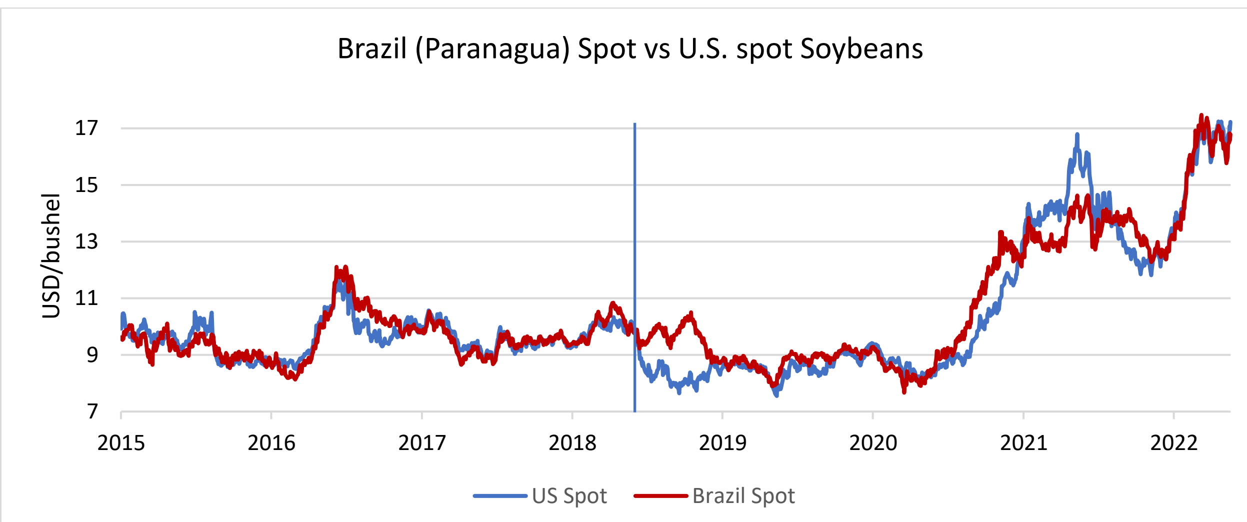

Figure 1: Soybean US and Paranagua Spot Prices (Source: Bloomberg)

The problem we address in this paper is the degree by which the information flow between U.S., Brazilian, and Chinese soybean futures markets have been impacted by import tariffs on U.S. soybeans. Information between economies is crucial for the global pricing of commodities and efficient markets in the short run, and towards rational expectations in the longer run (Bigman et al, 1983). In the case of price movements driven by Brownian motion processes, the independent

[2] CME and CBOT merged into CME Group in July 2017. We use CME throughout the article knowing it is CME Group. Online source: http://investor.cmegroup.com/news-releases/news-release-details/cme-and-cbot-complete-merger-creating-leading-global-financial

[3] USDA Foreign Agricultural Service (September 2019) "Oilseeds: World Market and Trade" (Westhoff et al, 2019).

increments of price movements are responses to incremental new sources of information to the global set of information. Even if the sources of information are hidden or ambiguous to one player in the market, the signals from those players to whom the new information is transparent is sufficient to move the market as a whole. The opening price in China, for example is not simply the previous closing price plus white noise, but the continuity of information signaled by changes in U.S. and Brazilian markets and its contemporaneous, newly formed, rational expectations on supply and demand at the Chicago and Brazilian futures markets. A price increase in the U.S. or in Brazil will signal some new information about either increasing demand or decreasing supply or some combination of the two. This signal will be transmitted and added to the information set compiled by Chinese traders in conjunction with their own supply-demand position. It is by this process that the U.S., Brazilian, and Chinese markets are cointegrated. The economic question is whether the continuity in information flow and cross-market signaling that we show below existed before the import tariffs on soybeans, remained continuous or became discontinuous after the import tariff was initially imposed?

Since 2012, China has become the predominant market for U.S. soybean exports (Gale et al 2019; Hansen et al., 2017). Core to our analysis are the price relationships between U.S. and Chinese futures prices traded at CME and DCE in Liaoning Province. We propose that the imposition of import tariffs on U.S. soybean exports to China has adversely affected the original pattern of price stability and signaling between trading partners. This has arisen from distortions, uncertainty, and ambiguity in the traditional supply-demand information flows in global trade, which has in turn disrupted the most basic elements of transparent price discovery. With pre-tariff trade between the U.S. and China so dominant in world soybean markets, economics would suggest that there is a strong informational flow based on respective demand and supply positions from close to open between the two markets. This proposition is supported by a significant amount of research that sheds light on both futures and spot price signaling effects between U.S. and Chinese markets. Fung et al. (2010) argue that there is a significant relationship between U.S. and Shanghai futures markets for copper and aluminum. Hua and Chen (2007) showed similar results and conducted research on more products including soybeans and wheat. Fung et al. (2003) proved that soybeans, with less Chinese governmental control, is subject to influence from the U.S. soybean futures market and that the U.S. futures market plays a dominant role in transmitting trading information to the Chinese market, although this dominant role may be fading as China's market power and internal pricing system matures (Liu et al. 2015; Ke et al. 2019).

Although there is significant bi-directional dependence between Chinese and U.S. markets across commodities, including soybeans, wheat, corn, and sugar, there is a general belief that tensions can arise from China's rising economic power (Gale, 2015) and that China's dependence on U.S. markets is greater than U.S. dependence on China's markets (Jiang, 2016) - a belief that is currently being challenged in the face of the overall trade war. Nonetheless, preceding the imposition of import tariffs on soybeans, multiple U.S. papers confirm the overnight return of U.S. soybean futures, and the daytime return of Chinese No. 1 soybean futures simultaneously affect each other (Li and Hayes, 2017; Zhang, 2015; Han et al. 2013)[4].

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[4] Li and Hayes (2017) find no correlation between U.S. and DFE #2 Soybean futures which are specific to GMO free soybeans.

Our paper is closely aligned with the in-depth investigation into the cointegration of soybean futures prices between U.S., China and Brazil by Li and Hayes (2017) but differs in two major respects. The first is the narrower scope of our study, which is short-run and deals only with the pricing of U.S. and Chinese soybean futures before and after the beginnings of the imposition of the import tariff in 2018. The second difference is our measurement of price changes. Li and Hayes (2017) investigate day-over-day changes in the closing prices of U.S. and Chinese futures contracts. In our study we are interested in the 'exchange basis' between U.S., Brazilian, and Chinese prices in their levels, and not their changes. That is, we are concerned with the relationship between the Chinese opening price against the previous U.S. closing price (or Brazilian closing price), and the U.S. opening price (or Brazilian opening price) against the previous Chinese closing price. We focus only on the CME and DCE trades and their respective effects on Chinese spot price. Overnight trading does occur on GLOBEX exchange in all markets, although these are less liquid. Also, we use DCE #1 soybean futures contracts that are priced to non-GM soybeans rather than the DCE #2 contracts which are of mixed blend.

In our preliminary analysis we found that the #2 contracts were less liquid, and the data had many missing data points that would interrupt the continuity of inter-temporal price flows required of our Vector Auto-Regression (VAR) time series analysis. This confirms similar findings reported in Li and Hayes (2017, p. 65) which shows that the day-to-day price changes in DCE #1 soybean futures contracts were more highly influenced by U.S. prices than #2 contracts. In their long run analysis based on changes in closing prices Li and Hayes (2017) find that a 1 percent change in U.S. futures prices increased China #1 contracts by 0.2189 percent, but the change in U.S. futures prices following a change in Chinese prices was not statistically different from zero in the most usual circumstances. Their shorter run investigation of nighttime GLOBEX trading showed a significant influence of GLOBEX nighttime trading on Chinese daily trading in 5 of 11 years, and again in a unidirectional way. No significance was found for #2 DCE soybean futures.

In comparison to previous studies, this paper differentiates price signaling effects between opening prices and closing prices of soybean futures, building on a circulating price signaling structure. We also consider signaling effects between U.S. soybean futures prices and Chinese spot prices, and Brazilian soybean futures prices and Chinese spot prices. Using vector auto-regression (VAR) we test the causal covariate differences in soybean futures prices before and after June 1, 2018.

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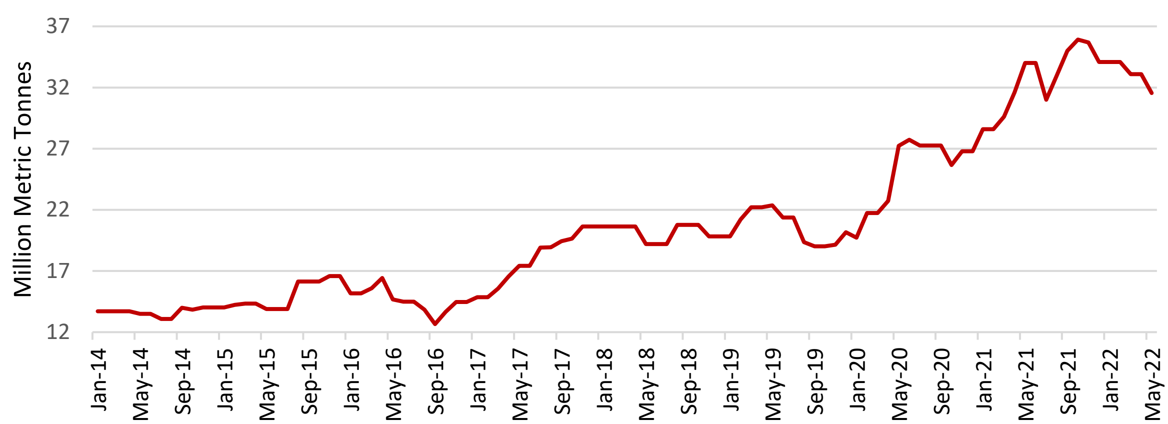
In comparison our results, with levels prices converted to logs, find bi-directional influence before the imposition of import tariff on soybeans with a 1 percent increase in CME-close leading an average 0.191 percent increase in DCE #1-open, and a 1 percent increase in the DFE-close, leading to a 0.272 percent increase in CME-open. To the point of our paper, after the imposition of import tariffs, the influence of the CME-close on DCE-open collapsed to insignificance, while the influence of DCE-close on CME-open fell by almost half to 0.148 percent and at a lower (but still acceptable) level of significance of about 5 percent.

Finally, our paper also considers the impact of the import tariff on Chinese spot prices for soybeans. In June 2018 as China's import tariffs were announced, soybean crops were already planted. The normal expectation suggests a storage equilibrium in which exports would deplete stores in elevators, to be replaced by the next harvest. With increased tariffs and an import embargo, many areas in the U.S. were unable to find storage off-farm. This pushed the 2018 soybean harvest into the cash market, widening the basis across the U.S., and putting downward pressure on spot prices. In contrast, the Chinese could (and did) replenish storage usually filled with U.S. imports, with imports from Brazil and Argentina, and were thus better positioned to maintain the basis (minimize the difference between futures and spot prices) and stabilize prices (see Figure 2).

Figure 2: China's projected ending stocks of soybeans (old and new)

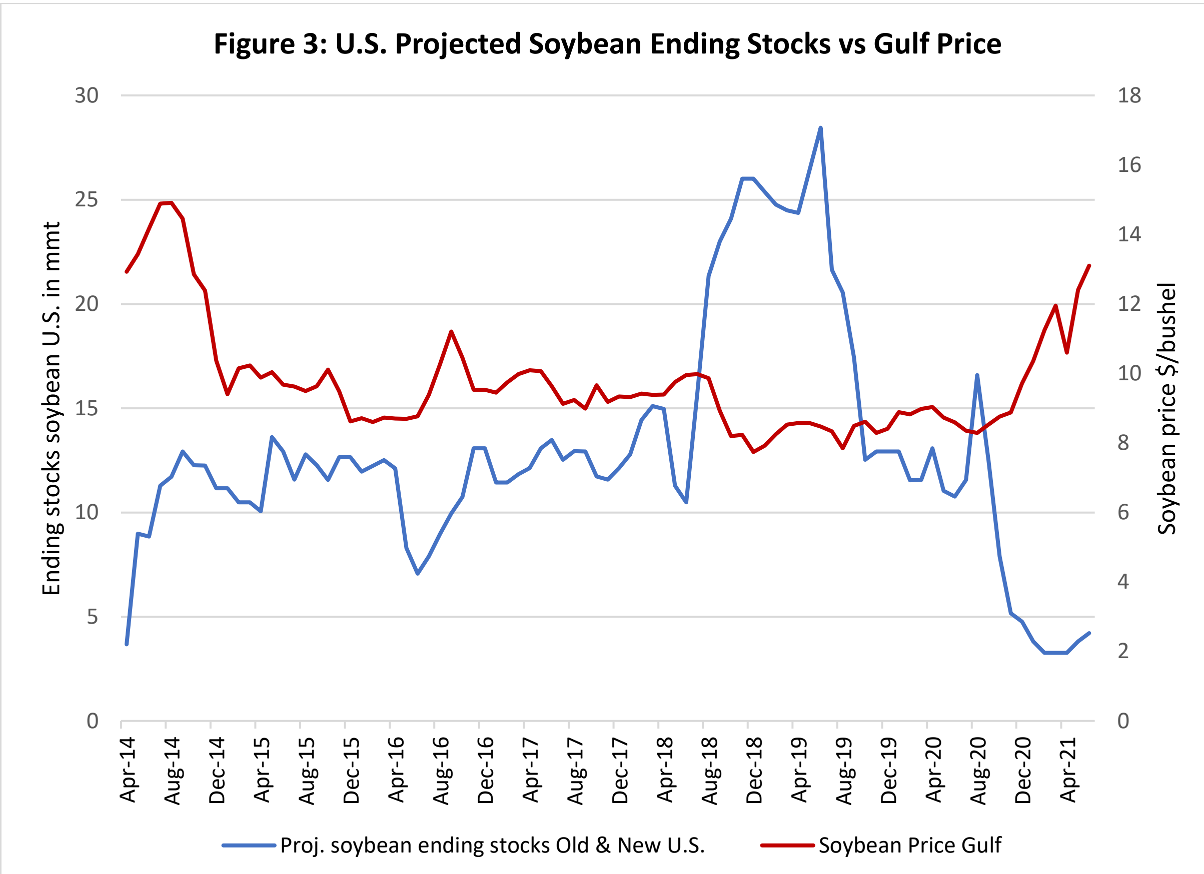


2. Background to China's Import Tariffs on U.S. Soybean Exports

To place these economic outcomes in perspective we examine here the trade relationships between China, the U.S. and Brazil. China is the largest soybean consumer in the world, consuming more than one third of the global supply in recent years. Domestic annual soybean production in China has never been greater than 20 million tons since 2005, but the demand for soybeans has continually increased from 45 million tons in 2005 to 108 million tons in 2018. Soybean supply was satisfied primarily by imports from the U.S. and Brazil. In 2017, the U.S. share of China's soybean imports was 65 percent (Brazil had a 20 percent share). By the end of 2022, these shares were 32 percent and 60 percent, respectively. Perhaps more significantly 56.7 percent of U.S. soybean exports went to China in 2017, peaking at 72 percent in 2014 but dropping in 2018 to 18 percent and then recovered to 52 percent in 2022.

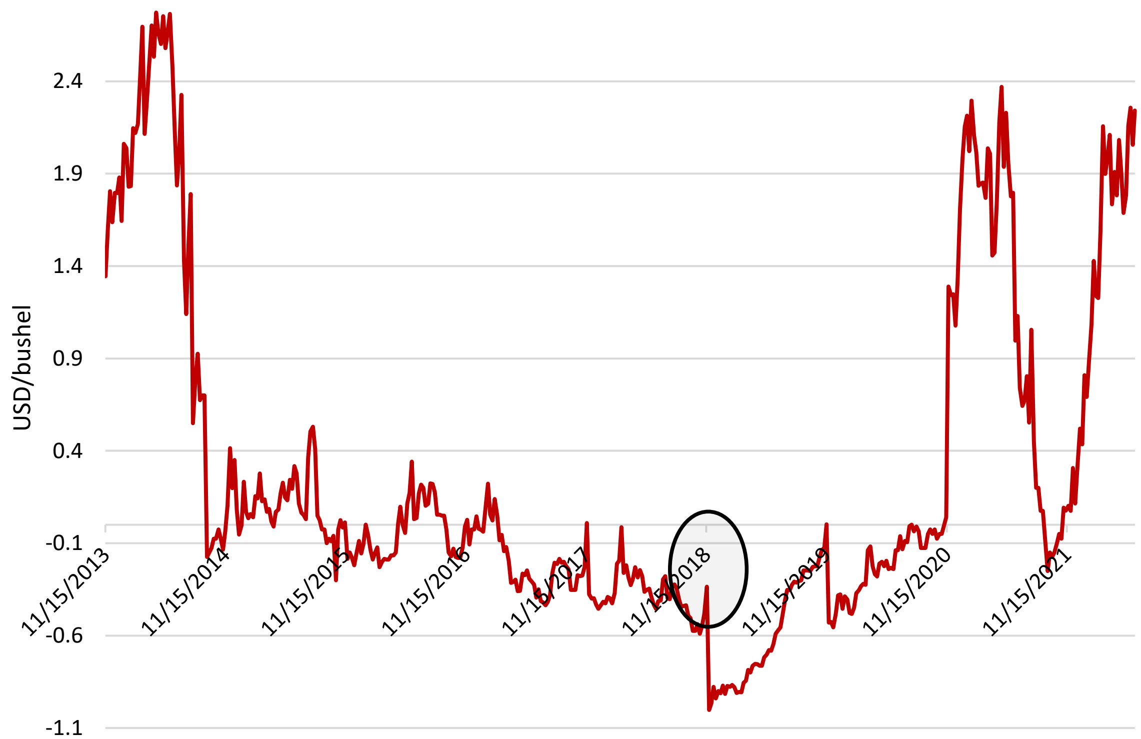
The competition between the U.S. and Brazil for China's soybean market becomes an important element to the events in 2018-2019 (Gale et al, 2019; Li and Hayes 2017). A 25 percent import tariff on U.S. soybean exports raised the price in China for consumers and crushers, while lowering the price to U.S. soybean farmers. With such a great reliance on the

China’s markets the U.S. export supply curve is likely highly price inelastic, particularly because China had an immediate source and supply chain to offset declines in U.S. soybean imports. (Hansen et al., 2017). The U.S. however did not have ready access to, or time to develop, alternative export markets in the short run. With a sharp and somewhat unexpected reduction in Chinese imports due to tariffs and the export embargo, U.S. soybean stocks did not decline through the crop year as it normally does. See Figure 3.



Consequently, the U.S. 2018 soybean crop was forced into the cash market, widening the basis, and decreasing spot prices even more significantly. In Figure 4 below, each November a current soybean futures contract expires. Notice the gap below the horizonal line, meaning that futures prices closed higher than spot prices at the expiry, which creates contango. In this situation, the holder of a long position in the futures contract would have to pay a premium to take delivery of the underlying commodity, since the futures price is higher than the expected spot price. The trader could choose to roll their position forward to a new futures contract, rather than taking delivery of the underlying commodity. In a contango market, this would typically involve selling the expiring futures contract and buying a new futures contract with a later expiration date. However, if the new futures contract is also trading at a premium to the expected spot price, the trader may face a cost of carry, which could erode their profitability.

Figure 4: CCY the difference between the cash prices and the harvest date futures price of the current soybeans crop year (weekly)



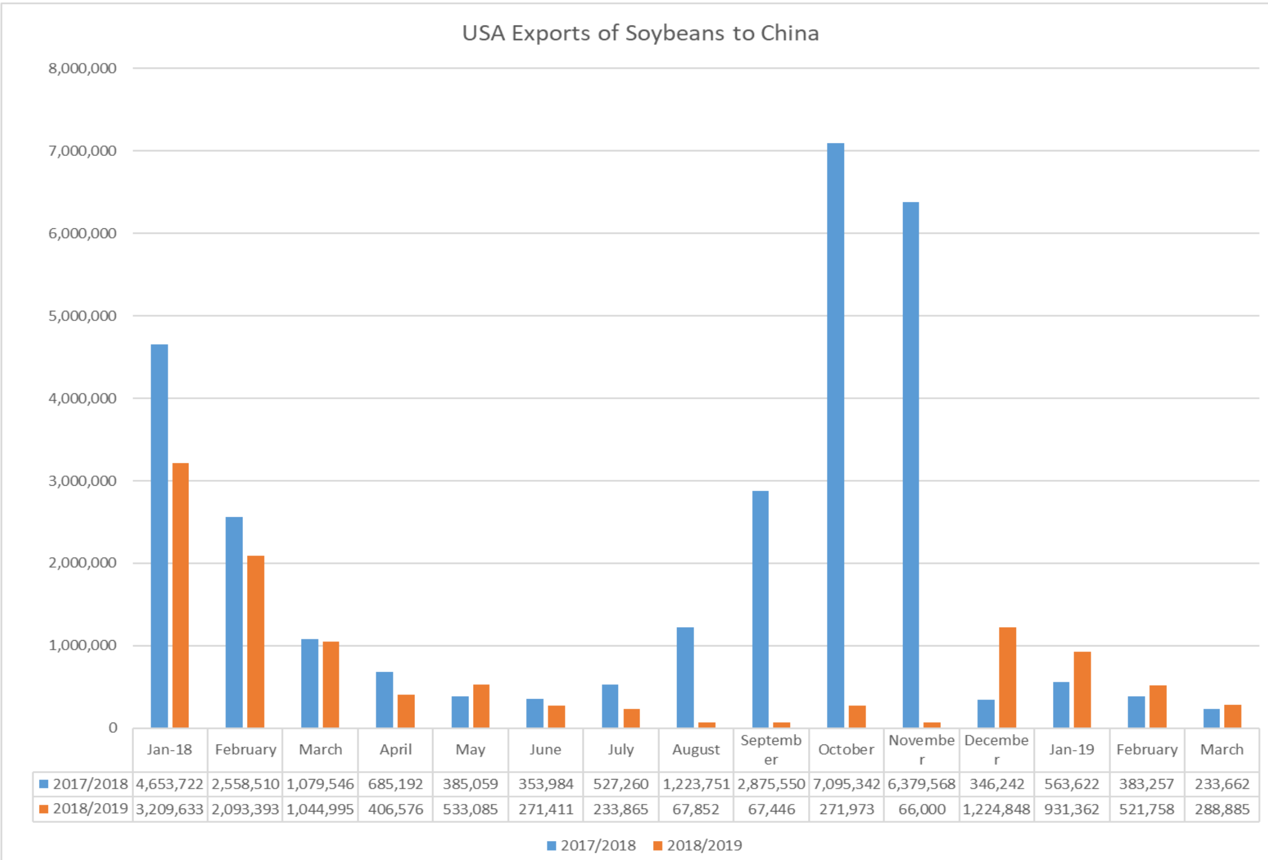
What was not immediately obvious as U.S. farmers harvested soybeans in 2018, was that China embargoed U.S. soybeans, so no U.S. soybeans were imported in October and November 2018 (see Figures 5a and 5b) with the difference made up from increased imports of soybeans from Brazil. Those soybeans that were not shipped to China would likely be dumped on the U.S. domestic market, causing spot prices to fall further, while beans remaining in storage, fell in quality (Zhou et al, 2018). Without adequate storage, unharvested acres doubled as a percentage of acres planted in 2018 relative to years before and after.[5]

The impacts of China's import tariffs are illustrated in Figure 5a which provides side-by-side comparisons of soybean exports to China in 2018/2019 compared to the previous year. Through the first 6 months of 2018 China purchased U.S. soybeans following its traditional cyclical pattern. This was fractured in June 2018 with imports falling to a low fraction of 2017 levels[6]. The Chinese embargo was lifted in December 2018 as a goodwill gesture to move forward with trade negotiations, but on May 13, 2019, in response to the administrations

[5] See U.S. Bioenergy Statistics – USDA ERS https://www.google.com/search?client=firefox-b-1-e&q=U.S.+Bioenergy+Tables%3A+All+tables+in+one

[6] Westhoff et al (2019) present results on the impact of import tariffs on U.S. soybean exports on the spread between Brazilian and the U.S. Between July 2017 and June 2018, the average spread between Brazil and U.S. was $15/ton in Brazil's favor. Between July 2018 and June 2019 that spread had increased on average to $35/ton. In October 2018 the spread peaked at $92/ton which corresponds with the beginning of embargo on U.S. exports and the replacement demand required of Brazilian soybeans. (see also USDA, 2019 for source material)

imposition of new tariff increases from 10 percent to 25 percent on $200 billion of Chinese exports, China announced further tariffs on $60 billion of U.S. exports and further retaliation. Soybean futures prices hit a new low of $7.89/bu. on that same day[7]. On May 30, 2019, reports from China indicated that it would end its goodwill purchases and resume its embargo on U.S. soybeans[8], while Brazil maintaining export premiums at Paranaguá compared to the CME.



	Jan-18	February	March	April	May	June	July	August	September	October	November	December	Jan-19	February	March
2017/2018	4,653,722	2,558,510	1,079,546	685,192	385,059	353,984	527,260	1,223,751	2,875,550	7,095,342	6,379,568	346,242	563,622	383,257	233,662
2018/2019	3,209,633	2,093,393	1,044,995	406,576	533,085	271,411	233,865	67,852	67,446	271,973	66,000	1,224,848	931,362	521,758	288,885

Figure 5a: U.S. exports of Soybeans to China, Metric Tons, 2018/2019 (Source: USDA ERS)

[7] Soybean prices rose sharply between May 13th and May 30th 2019 as harvest amounts were reduced as a result of unprecedented rainfall and flooding in the Midwest, resulting in planting by late May 2019 at about 58% compared to a long run average of 90%, with key states such as Illinois, Indiana, Michigan and Ohio recording 35%, 22%, 33% and 22% respectively.(Source: USDA Crop Progress Report, May 28th 2019, USDA NASS. https://release.nass.usda.gov/reports/prog2219.pdf). Even with the announced embargo, soybean futures prices for July 2019 delivery rose by about $0.76/bu to $8.794/bu as supply concerns overshadowed embargo fears.

[8] Bloomberg News, May 30, 2019 "China Puts U.S. Soy Buying on Hold as Tariff War Escalates" https://www.bloomberg.com/news/articles/2019-05-30/china-puts-u-s-soy-purchases-on-hold-as-tariff-war-escalates

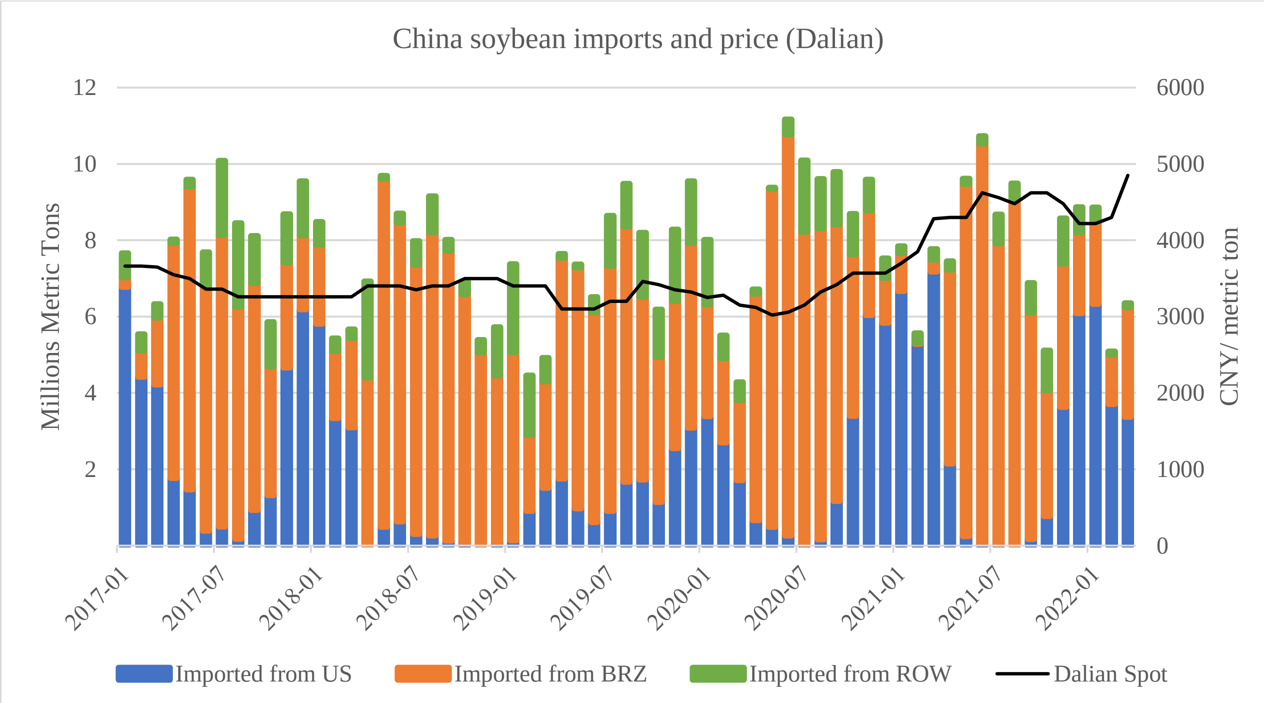


Figure 5b: China imports from U.S., Brazil, and ROW, Metric Tonnes, 2017/2022 (Source: Bloomberg)

With an average of 28 percent of U.S. soybean production being exported to China from 2013 to 2017 (peaking at 40 percent in 2013), the import tariff induced China to increase imports from Brazil, thereby mitigating the tariff effects on domestic Chinese prices. However, with such a reliance on China, U.S. futures and cash prices plummeted, imposing unexpected hardship on U.S. soybean farmers. See accompanying Figure 6.

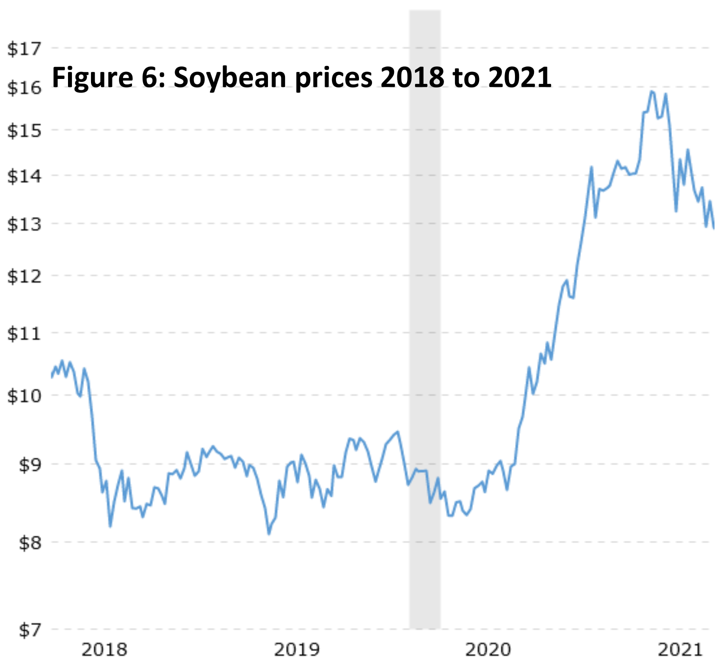


Figure 6: Soybean prices 2018 to 2021

In 2017 about 30 percent of U.S. soybean production was exported to China[9]. With soybean yields reaching a record 4.59 billion bushels in 2018 economic losses due to price declines were significant[10]. On the one hand, high yields partially offset the

[9] Crop exports to China were 36.249 million metric tons or 1.332 billion bushels in 2016/2017 (US Soybean Export Council Snapshot https://ussec.org/resource-category/market-snapshots/). 2017 harvest was about 4.406 billion bu. In 2017 (USDA NASS "USDA Forecast Record High Corn Yield and Soybean Production for 2018" https://www.nass.usda.gov/Newsroom/2018/08-10-2018.php). 1.332/4.406 – 30.22%.

[10] US Soybean Export Council Snapshot https://ussec.org/resource-category/market-snapshots/

costs of the tariff; on the other hand, high yields contribute to the soybean price fall. On May 29, 2018, the CBOT May-2019 soybean futures price was $10.44/bu. One year later, as of May 28, 2019, the price was $8.74/bu. The lowest price of $7.89/bu. was recorded on May 13, 2019, as China announced renewed tariffs in response to expanded tariffs imposed by the U.S. These numbers suggest significant losses of somewhere between $7.8 and $11.7 billion per year[11]. At the local level a soybean enterprise budget provided by Schnitkey (2016) suggest that the breakeven prices including land costs are $9.41/bu. on a profit basis (including depreciation) and $8.40/bu. on a cash basis. To offset these losses the Secretary of Agriculture announced on May 23, 2019, of up to $16 billion in assistance to farmers affected by the overall imposition of China's import tariffs on agricultural products including soybean farmers. Affected crops include soybeans, corn, wheat, cotton, rice, sorghum, milk, pork, fruits, nuts, and other crops[12]. The allocation to soybean farmers was $6 billion[13] but was below the loss estimates described above, leading to sustained stress to soybean producers at least through 2019. Apart from the clear stressor to the U.S. agricultural economy, there are related – and perhaps longer term – impacts on the informational content and price signaling apparatus of U.S. (CME) and Chinese (Dalian) futures exchanges.

Despite having Chinese tariffs on U.S. soybeans, in 2020 we see a return to the previous normal for U.S. soybean imports. Although the import tariffs remain to this day, most Chinese importers are government owned entities who can request exceptions for their imports[14] (and even waive for private trading firms importing). Finding an exact date for "return to new normal" is ambiguous, which we can see mostly through the uptick in imports. Most likely explanation is that having both Brazil and U.S. as the main source of import countries guarantees continuous annual flow of soybeans, which can be offset by the other country during lower harvests. Additionally, the U.S. and Brazil harvest seasons are in different times of the year. The U.S. harvest starts around September, while in Brazil it starts around January. This cyclical patter can be seen in Figure 5b, where we can see that pattern of production and later exports to China. Rest of the world (ROW) countries have only a minor share of soybean exports to China when compared to the total amount from Brazil and the U.S.

Ag Decision Maker, March 2019, Iowa Cash Corn and Soybean Prices, Iowa State University https://www.extension.iastate.edu/agdm/crops/pdf/a2-11.pdf

[11] Preliminary estimates of losses for soybeans by Zheng et al (2018, Table 3) using the Global Simulation Model (GSIM) was a decrease in producer surplus of 4%, for losses to soybean producers in the order of $1.847 Billion. There is no suggestion in their paper of the impact of embargo, which at the time they were preparing their paper, would not have been anticipated. Westhoff et al (2019) investigate the trade patterns and confirm a nearly 1:1 ratio of export decline/incline between the US and Brazil. Their baseline trade model for 2019/2020 with tariffs in place suggest 16.2 mmt in US-China soybean trade and 67.2 mmt for Brazil. Removal of tariffs would increase soybean exports to 33.0 mmt, but only 9.9 mmt is drawn from Brazil.

[12] USDA, "USDA Announces Support for Farmers Impacted by Unjustified Retaliation and Trade Disruption" Press Release No. 0078.19. May 23, 2019. Washington DC. https://www.usda.gov/media/press-releases/2019/05/23/usda-announces-support-farmers-impacted-unjustified-retaliation-and

[13] USDA Foreign Agricultural Service. (2018, December 20). Market Facilitation Program. Retrieved from https://www.fas.usda.gov/programs/market-facilitation-program

[14] Cowley, C. (2019). Reshuffling in Soybean Markets following Chinese Tariffs. Agricultural and Resource Economics Review, 48(1), 128-157. doi: 10.1017/age.2018.12

3. The Economic Framework

The economic signaling between a dominant demand center and a dominant supply center relies on informational signaling across market boundaries to establish full transparency in price discovery. We set up the economic framework using classical three-panel trade diagram where an import tariff reduces world prices to P_X for the exporter to and increase domestic prices in China to P_M (trade levels decline). Figure 7 implies the price transmission between U.S. and Chinese market prices are now less than 1 due to the tariff, the extent to which depends on the relative elasticities of excess supply and demand, and on the level of the tariff. This has important implications for price discovery in our statistical analysis to follow.

Furthermore, it was not immediately obvious in June 2018 that in addition to the tariffs, China would retaliate further with non-tariff measures, the most significant being embargo and the moral suasion of Chinese crushers to increase imports from Brazil at the expense of U.S. orders (this being reflected in the price premium for Brazilian soybeans over U.S. prices for the six-month time period ending in November 2018). The effect of an import embargo on U.S. soybean exports would sever the link between U.S. and Chinese market prices, just like an import quota would in the supply/demand analysis in Figure 7: the excess demand curve facing the U.S. would be vertical. This reduces U.S. exports even further, putting greater downside pressure on U.S. soybean prices This is a direct consequence of commitments by (state and private) importers, crushers, and further processors to refuse U.S. soybeans regardless of the price. Consequently, the total trade volume decreased, together with a higher import price in China and a lower export price in the U.S. Consequently, price signals between Chinese and U.S. soybeans weaken even further, and the U.S. domestic soybean price would no longer effectively influence international and Chinese markets. This is core to the economic analyses presented in this paper.

Figure 7 assumes that China has no additional source of soybeans to import. However, as shown in Figures 5a and 5b, China's demand exceeded that exported by the U.S. with the bulk of the supply shortage coming from Brazil. Muhammad et al (2018; Table 3), for example, argue that supply shortages due to tariffs on U.S. soybeans would be replaced on almost a 1:1 basis by Brazil in the short run. This is precisely what happened. To show the impacts of a competing exporting fulfilling the void, consider Figure 8. Brazil's exports are large enough to backfill China's reduced imports from the U.S. if an import tariff is imposed (not shown). So why was there a price premium on Brazilian soybean prices for six months ending in November 2018? It was likely due to the need to fulfill China's soybean processors demand for soybeans until the next U.S. soybean harvest (and in anticipation of the Southern hemisphere production months later).

Figure 7: The Effect of an ad valorem import tariff on U.S. and China's Soybean Market

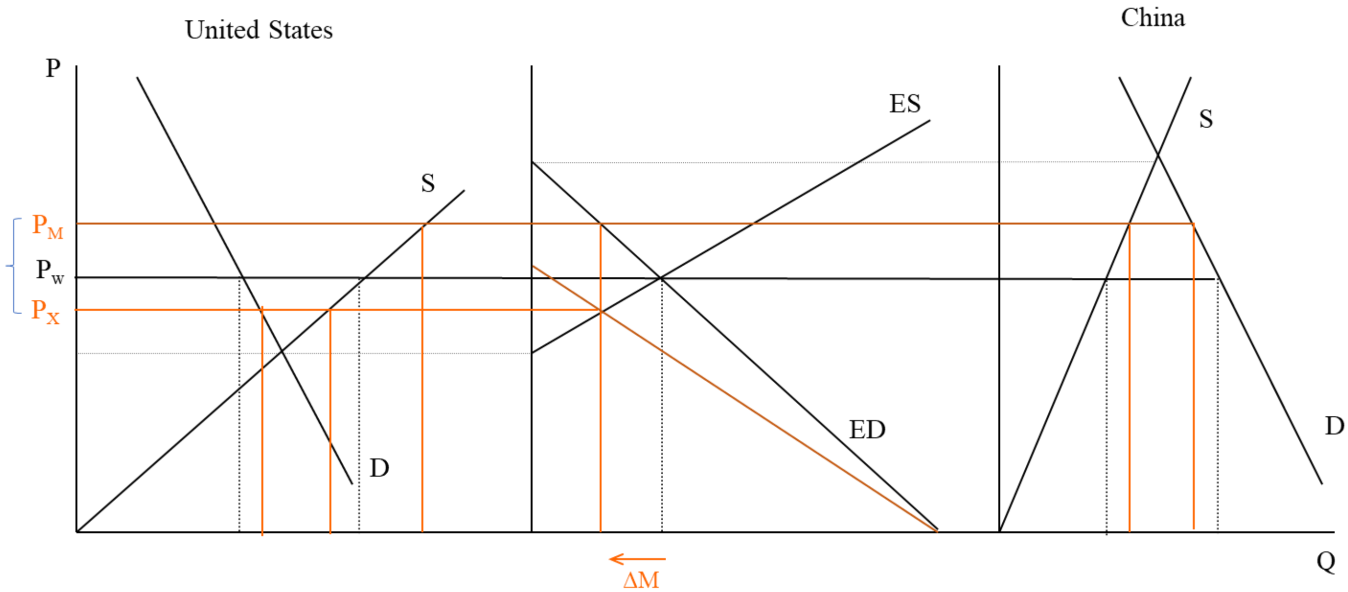
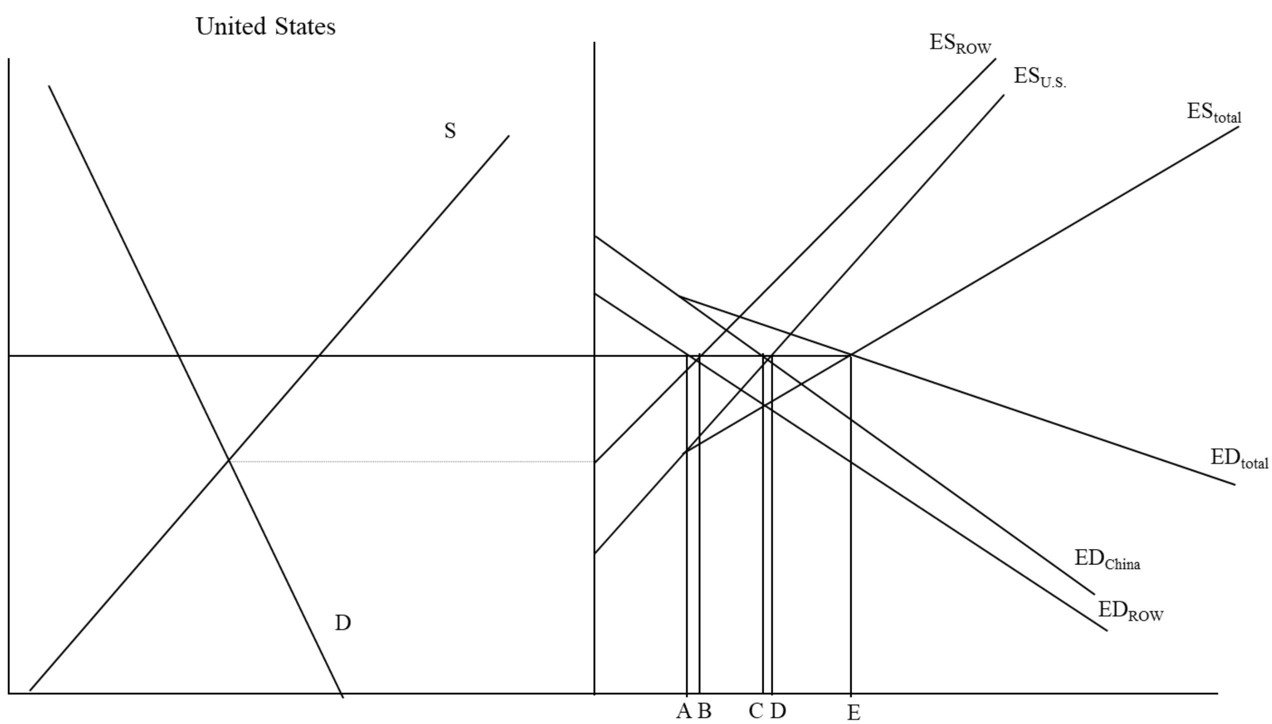


Figure 8: Pre-import tariff, Brazil's exports are large enough to fill the void if China reduces demand for U.S. soybeans



4. Price Discovery

Our goal in this paper is ultimately to examine the relationship that the imposition of import tariffs by China on U.S. exports of soybeans had on the information flows and market signaling between the U.S., Brazil, and China. It is certain that China, Brazil, and U.S. markets were? actively integrated. However, unlike previous studies, which focused mainly on the settlement prices or closing prices in the two markets, the relationship between the futures markets will not be fully discovered until we comprehensively understand the patterns and prices in? these markets.

The Chinese futures markets opens from 9:00 am to 11:30 am and from 1:30 pm to 3:00 pm, while the Chicago market opens at 8:30 a.m., closing at 1:20 p.m. (with overnight GLOBEX trading between 7:00 p.m. and 7:45 p.m. Central Time). We use the CME final or settled price which is reported around 3pm daily. There is 7.5-hour time difference between the Chicago close and DCE open, and a 5.5-hour difference between the DCE close and the CME open. Thus, the opening bid in China, prior to the import tariff, would receive as an informational signal the closing or settle price in Chicago 7.5 hours previous. Likewise, the opening bids in Chicago would rely on the information content contained in the closing prices in Dalian, 5.5 hours previous.

For Brazilian soybeans we use Cash-Settled Soybean Futures Contract at the Price of the CME Group Mini-Sized Soybean Futures Contract (SJC). This market opens at 6:00 a.m., closes at 1:20 p.m. Central Time. It implies that Brazilian soybeans market opens 2.5 hour ahead of the Chicago market. In this case, the opening time in Brazilian markets may send price signals to Chicago opening market. With the Chinese market, Brazil east is 12 hours behind Dalian time. Hence, we can test B3 closing prices against next day's DCE opening prices, and DCE closing prices with B3 opening prices.[15]

Due to time difference between the two countries, the Chinese futures market, Brazilian and the U.S. futures market are not trading simultaneously. The trades for soybean futures on the CME are typically executed from 8:30 am to 1:20 pm. For Brazil it starts at 6:00 am to 1:20 pm Central Time. This time period is not a trading window for China. In China, the DCE is open from 9:00 am to 3:00 pm, during which period the exchange accepts and matches orders for soybean futures. Since the two markets trade in a sequential order, traders will look at the performance in the other country and make their own trading strategies for the day, thereby integrating prices and markets. The relationship is therefore a sequential one.

In this paper, we will address this issue by co-integrating different price pairs according to sequence of time:

1. CME closing price and DCE opening price
2. DCE closing price and CME opening price
3. Chines spot prices and all futures prices
4. B3 closing price and DCE opening price

[15] Links: https://www.b3.com.br/en_us/solutions/platforms/puma-trading-system/for-members-and-traders/trading-hours/derivatives/commodities/

5. DCE closing price and B3 opening price

5. Data

Data is taken from Bloomberg terminal. We focus on soybean futures prices and spot prices for both the U.S., Brazilian, and Chinese markets. The data collected includes opening price, closing price and settlement price of both markets, CME, DCE (soybean #1 futures contract), and B3 Cash-Settled CME Mini-Sized Soybean Futures.

Date-matched time series were collected from the Bloomberg database from January 4, 2016, to August 22, 2022, including periods both before and after the imposition of import tariffs on U.S. exports. Due to difference in holiday periods in the two countries, some data between China did not corresponding with trading dates in the U.S., and vice versa. To address this problem, we used linear interpolation to fill in single day missing data and deleted unmatched daily observations if missing for more than two successive days. The data observations are provided in Table 1:

Essentially, we are looking at three periods. The Pre-Import Tariff period starts from January 2016 until July 2018. The Import Tariff period lasts from July 2018 to September 2020. All dates after September 2020 are part of Post-Import Tariff period, as can be seen in Figure 9 below.

Data pairs	Number of observations
Period I: Pre-Import tariff	
CME close & DCE open	489
DCE close & CME open	489
B3 close & DCE open	498
DCE close & B3 open	333
Period II: Import Tariff	
CME close & DCE open	484
DCE close & CME open	484
Period III: Post-Import Tariff (Sept 2020 onwards)	
CME close & DCE open	444
DCE close & CME open	444
Period II + Period III for Brazil	
B3 close to DCE open	895
DCE close to B3 open	539

Table 1: Data description

Estimation process with Vector Autoregressive (VAR) Model

Our analysis employs the vector autoregressive (VAR) model which is a generalized univariate autoregressive model allowing time series variables to be estimated simultaneously as a combined system, capturing intertemporal effect among variables, m, and a means to determine causality effect. Its general form for 3 equations with p lags - VAR(p) - is:

$$y_{1,t} = \alpha_1 + \beta_{1,1} * y_{1,t-1} + \beta_{1,2} * y_{2,t-1} + \beta_{1,3} * y_{3,t-1} + \varepsilon_{1,t}$$
$$y_{2,t} = \alpha_2 + \beta_{2,1} * y_{1,t-1} + \beta_{2,2} * y_{2,t-1} + \beta_{2,3} * y_{3,t-1} + \varepsilon_{2,t}$$
$$y_{3,t} = \alpha_3 + \beta_{3,1} * y_{1,t-1} + \beta_{3,2} * y_{2,t-1} + \beta_{3,3} * y_{3,t-1} + \varepsilon_{3,t}$$

In the above example, each variable in the combined system is estimated using lags of itself and the other two variables under the assumptions that $E[\varepsilon_{i,t}] = 0$: every error term has zero mean; $E[\varepsilon_{i,t}, \varepsilon'_{i,t}] = \Omega$: covariance matrix for same period error terms is Ω; and $E[\varepsilon_{i,t}, \varepsilon'_{i,t-k}] = 0$: there is no serial correlation in error terms. If the estimation of any coefficient in β is significant under a chosen significance level, then the variable is possibly a cause of a dependent variable. Our discussion focuses mainly on three time series: the soybean futures price in the CME, soybean futures price in the DCE, soybean futures price in B3 (through CME), and soybean spot prices in China. To be precise, we use either the opening or closing price rather than just the settlement price when testing causality effects.

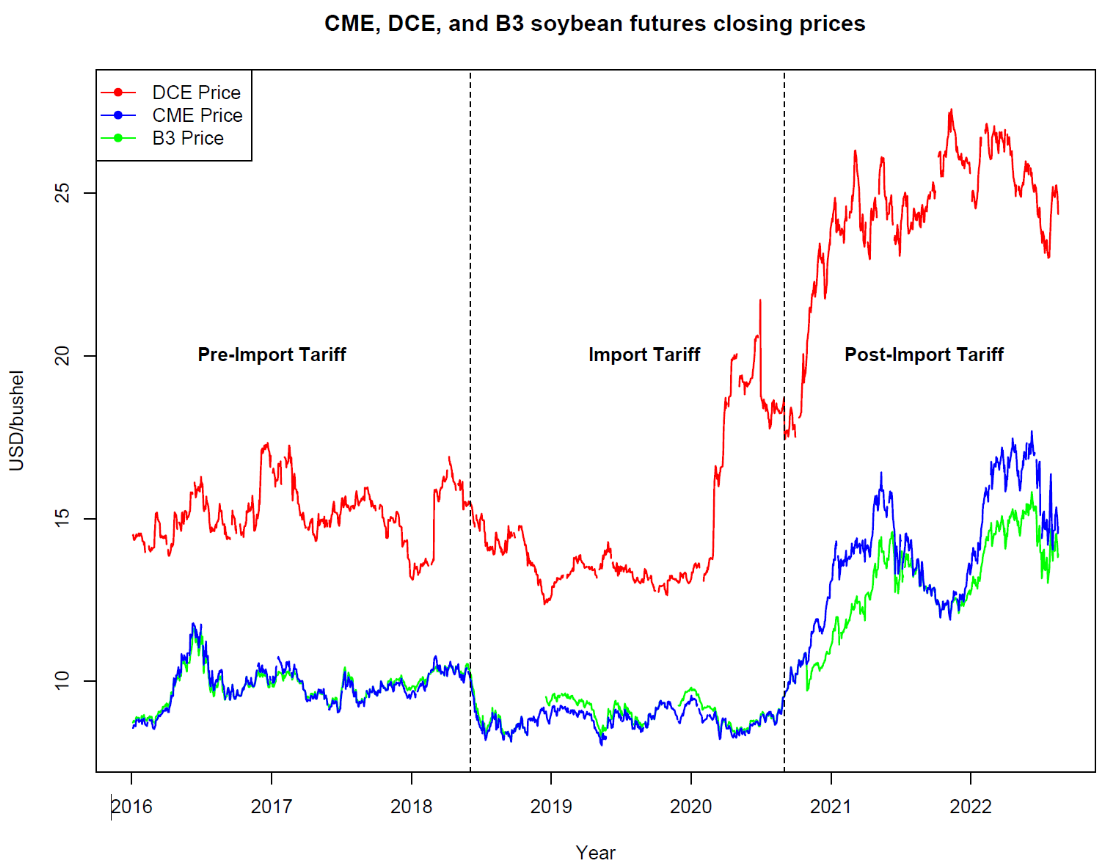


Figure 9: Time periods and closing prices for CME, DCE and B3

Intuitively, the number of lag periods to be included should be 1.0. The order of lag was determined within R based on assessing the likelihood ratio (LR), final prediction error (FPE), Akaike's Information Criterion (AIC), Hannan-Quinn Information Criterion (HQIC), and Bayesian information criterion (BIC). The Dickey-Fuller test confirmed that the time series were stationary in differences and contained a unit root. Serial correlation was examined and rejected using the Lagrange Multiplier Test. System stability and robustness was verified using the Eigenvalue test.

Our proposition is that there are strong causal relationships between U.S. and Chinese and Brazilian and Chinese futures prices and Chinese spot prices; that the economic prices are cointegrated to such an order that tariffs and related trade disruptions will affect the information flow between futures markets and (statistically) the degree of cointegration. To determine causality, we employ the Granger Causality Test. Causality refers to two properties: first, the cause (i.e., import tariffs followed by an import embargo) happens prior to the effect; and second, the cause has unique information (i.e., CME close influences DCE open, and vice versa) about the future values of effect[16]. The general form of regressing a price of interest (e.g., CME soybean futures)) against its own lag and the lags of the complementary cointegrated time series (e.g., DCE soybean futures and CME or B3 prices) was (for two lags):

$$y_{1,t} = \beta_{1,1} * y_{1,t-1} + \beta_{1,1-} * y_{1,t-2} + \beta_{1,2} * y_{2,t-1} + \beta_{1,2-} * y_{2,t-2} + \beta_{1,3} * y_{3,t-1} + \beta_{1,3-} * y_{3,t-2}$$

$$y_{2,t} = \beta_{2,1} * y_{1,t-1} + \beta_{2,1-} * y_{1,t-2} + \beta_{2,2} * y_{2,t-1} + \beta_{2,2-} * y_{2,t-2} + \beta_{2,3} * y_{3,t-1} + \beta_{2,3-} * y_{3,t-2}$$

$$y_{3,t} = \beta_{3,1} * y_{1,t-1} + \beta_{3,1-} * y_{1,t-2} + \beta_{3,2} * y_{2,t-1} + \beta_{3,2-} * y_{2,t-2} + \beta_{3,3} * y_{3,t-1} + \beta_{3,3-} * y_{3,t-2}$$

6. Results from the Vector Autoregressive (VAR) Model

The VAR results presented in Figures 10, 11, 12, and 13 capture the essential elements of the effects of the import tariffs on CME, B3 and DCE futures prices, and the Chinese spot price. All values were converted to natural logarithms so that the coefficients can be interpreted in percentage (%) terms. Because of space limitations we do not present the entirety of our results, nor the various statistical tests deployed. The statistical validity of the results holds under the Lagrangean multiplier test. References to directions of causality implied by the VAR regressions were verified by Granger causality. Because we found Granger consistency across all regressions, we do not report the Granger results explicitly.

[16] These two properties can be summarized by the following inequality: $P(X_{t+1} \subseteq S | I(t)) \neq P(X_{t+1} \subseteq S | I_{-Y}(t))$ Given past data of time series Y, the probability of future value of X falling into a non-empty set is different from that probability when Y is unknown.

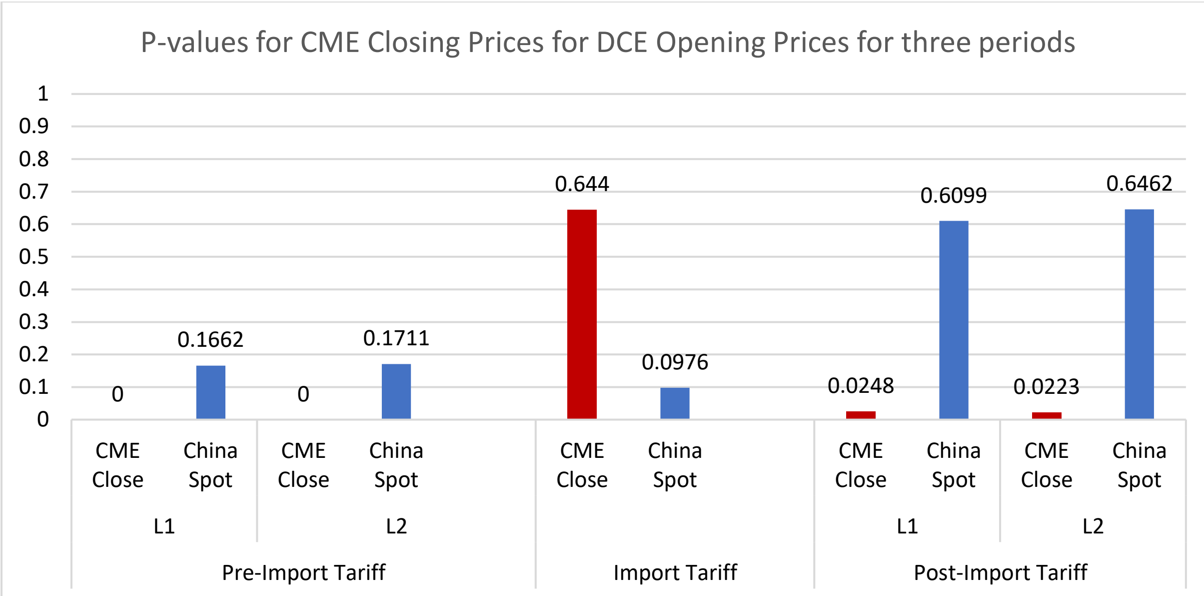


Figure 10: P-values for signaling from CME Close to DCE Open

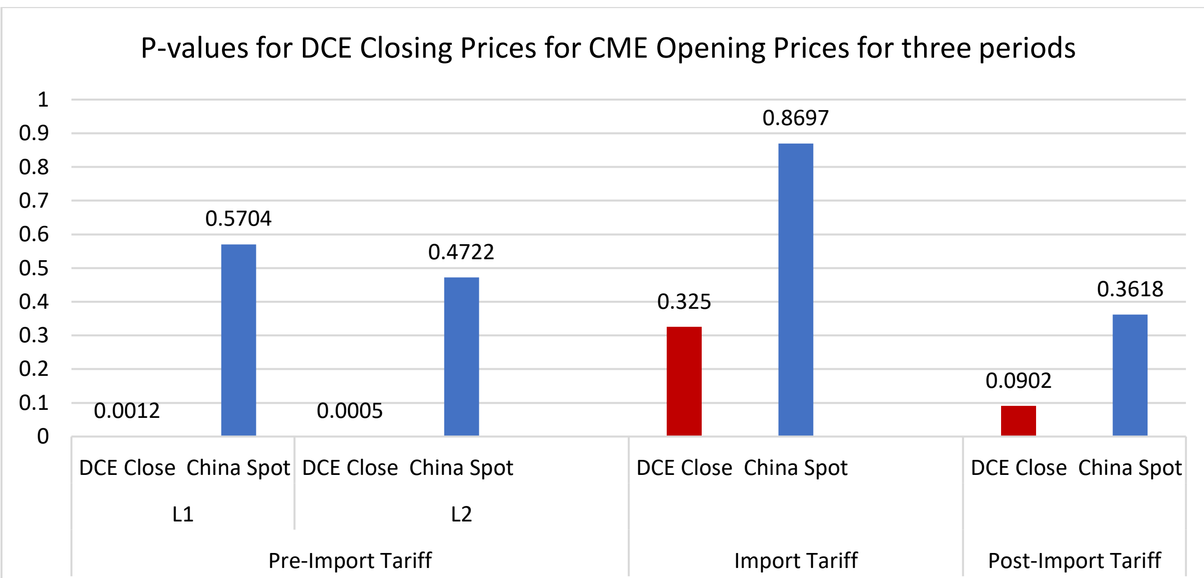


Figure 11: P-values for signaling from DCE Close to CME Open

As we expected there was a strong relationship between the CME and DCE futures contracts prior to the imposition of import tariffs on U.S. soybean exports. These VAR results are provided in the upper Figures 10 and 11. All of these are significant at the 1 percent level or better.

But as we also suspected, these economic relationships have been fractured since, and by, import tariffs. Import tariff VAR results are provided in Figures 10 and 11, under Import Tariff. There, we find no relationship between the CME closing price and the DCE opening price. We do find that the link between the DCE close and CME open deteriorates as the level of significance falls from p < 1 percent to p = 0.325. The significance level between the CME close and DCE open falls from p < 1 percent to p = 0.644. In other words, prior to the import tariff we find strong informational correspondence between the CME closing price and the DCE opening price, and the DCE closing price and the CME opening price, but after the imposition of import tariffs it appears that the CME close no longer signals the DCE open and vice versa.

Surprisingly, in the Post-Import Tariff period, we see that signalling from CME close to DCE open increases to p < 5% or p = 0.025. The opposite signalling from DCE close to CME open also increases to p < 10% or p = 0.09. This shows that despite the tariffs in place, China started to import more soybeans from the U.S., which is also reflected in the price signalling in futures markets. However, the link is not as significant as it used to be before the import tariff.

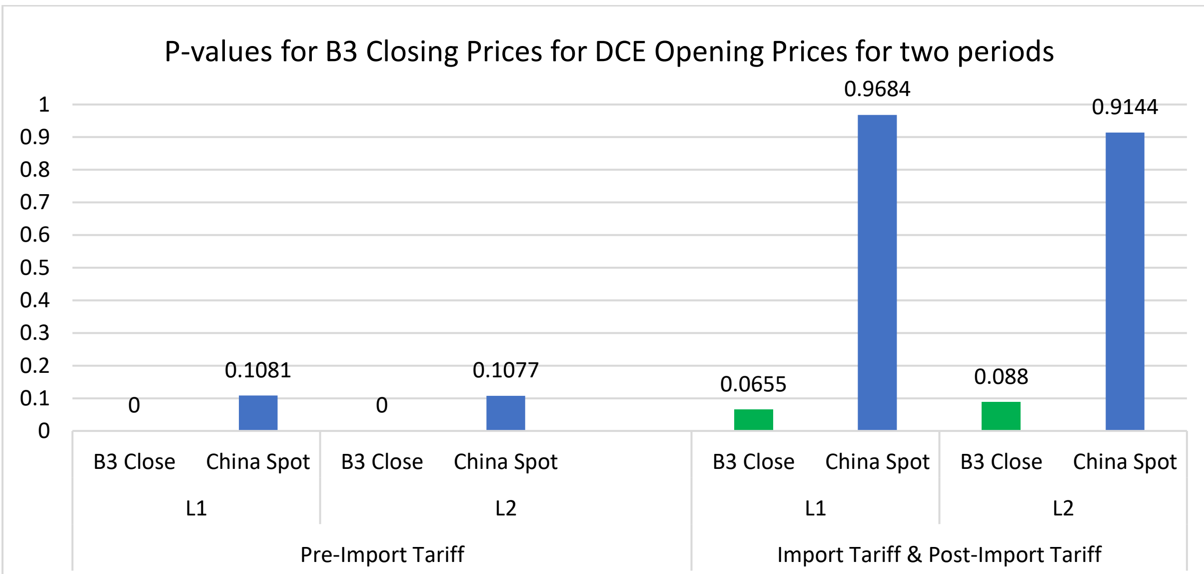


Figure 12: P-values for signaling from CME Close to DCE Open

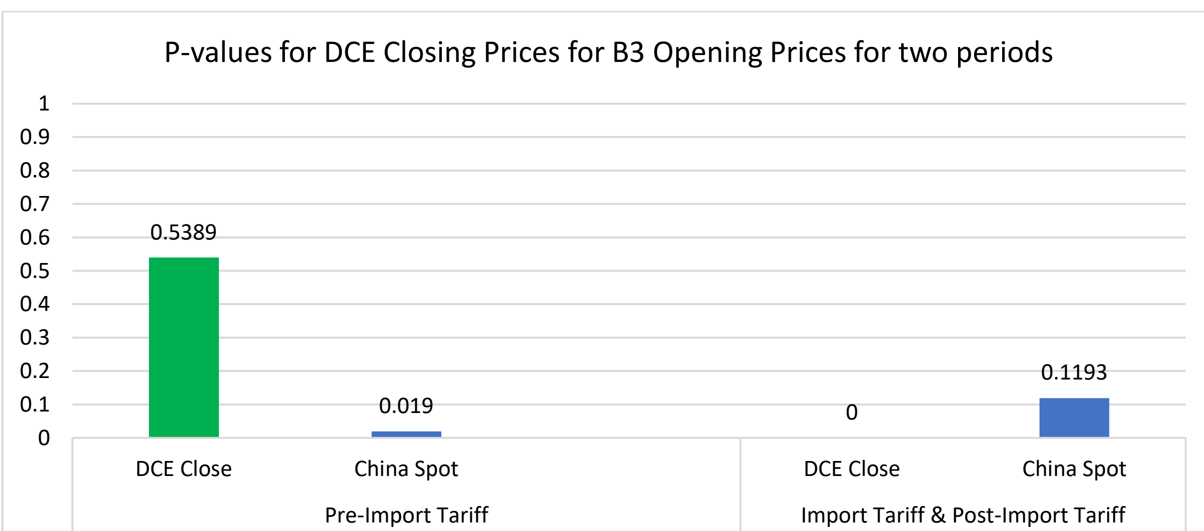


Figure 13: P-values for signaling from DCE Close to B3 Open

In Figures 12 and 13, we have the Brazilian B3 prices and DCE prices. In the Pre-Import Tariff on Soybeans period, there was signalling link from B3 close to DCE open at the significance level $p < 1$ percent. However, no signalling the opposite way from DCE close to B3 open with $p = 0.5389$. This can be explained by the fact that prior to mid-2018, the U.S. was the main supplier of soybeans. This rapidly changed after the tariffs were imposed by China on U.S. soybean exports. We first see that the significance level decreased for B3 close to DCE open to $p = 0.09$ for the second lag. But the significance level of DCE close to B3 open increased to significance level at $p < 1$ percent. This happened because China shifted their focus strictly on Brazilian soybeans for a while. It made Brazil the main exporter, even after China restarted importing U.S. soybeans in 2020. Brazil becoming the new main supplier for China, will in return be more impacted by Chinese prices than before.

7. Concluding Remarks

The import tariffs imposed on U.S. soybean exports to China has imposed economic challenges on both countries. Retaliatory tariffs on U.S. agricultural commodities have resulted in particularly acute stresses, with U.S. soybean producers being hit particularly hard as cash prices fell $2/bu in mid-2018 (see Figure 6). In addition to economic loss, this paper has examined the disruption of, and a discontinuity in, the information content of price signaling between the U.S. futures (CME) and spot market, and the Chinese (Dalian) futures and between the Brazilian futures (B3) and spot markets, and the Chinese (Dalian). We use VAR to estimate the circular price signaling structure between China and U.S. soybean futures prices, including two opening prices and two closing prices and examine the relationships between U.S. soybean futures prices and the Chinese spot price of soybeans. We find that the U.S. and Chinese markets endogenously shared information via price signals before the imposition of import tariffs on U.S. soybean exports. First, we detected circular relationships between the two futures markets using the opening and closing price of the two markets.

However, once the soybean import tariffs were imposed, these relationships lost economic significance. We conclude that the import tariffs fractured pre-existing soybean trading signals in both the futures market and the spot market. Based on this evidence we conclude that China's retaliatory tariffs and ensuing embargo on U.S. soybeans has significantly and adversely affected the efficiency of the soybean markets. This was somewhat restored in 2020, when China restarted their soybean imports from the U.S. This proved to also restore, to a certain extent, the efficiency and price signalling in the futures markets.

Evaluating the Brazilian case, we see that there was efficient signalling coming from B3 close to DCE open, and the opposite way. This changed after 2020 when U.S. exports returned to normal (official import tariffs were waived), as Brazil became the main exporter of soybeans to China and signalling from DCE close to B3 open strengthened to new levels. It requires further research to evaluate the impact of this signalling shift from CME to B3. We can tentatively conclude that Brazil became the new market maker due to China's import tariffs on U.S. soybean exports.

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