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Estimating the Market Effect of a Trade War: The Case of Soybean Tariffs

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Abstract:

In 2018, China retaliated to U.S. trade action by levying a 25% retaliatory tariff on U.S. soybean exports. That tariff shifted market preferences so that Chinese buyers favored Brazilian soybeans. We use the relative price of a substitute (RPS) method to estimate that the resulting trade disruption effectively drove a wedge into the world soybean market, lowering U.S. prices at Gulf export locations by \$0.65/bu on average for about five months, and increasing Brazilian prices by about \$0.95/bu, compared to what would have been observed without the tariff in place. It is likely that the impact of China's tariff on producers and purchasers of soybeans across the United States was heterogeneous and affected by local factors like transportation infrastructure, storage capacity, and crush facility proximity.

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In 2018, several of the United States' major trading partners placed retaliatory tariffs on U.S. agricultural exports in response to U.S.-initiated tariffs on washing machines, solar panels, steel, aluminum, and a range of Chinese products.¹ According to Congressional Research Service (2018b), a collection of the United States' top trading partners, led by China, announced new tariffs directed at \$26.9 billion in 2017 U.S. agricultural exports, or 18 percent of all U.S. agricultural exports that year (CRS, 2018b). In 2017, USDA estimated that agricultural exports represented 33.4 percent of total gross cash U.S. farm income (Schnepf 2017), so export disruptions of this size have the potential to cause significant harm to U.S. agricultural interests. Throughout this paper, we refer to the rising tensions and new trade barriers as a "trade war."

U.S. soybean exports were easily the foremost target of (agriculturally-directed) trade retaliation, accounting for \$12.3 billion in threatened U.S. exports (in 2017, the year before the trade disruption)—nearly half of the total trade war retaliation—all directed by China, historically the United States' main soybean export destination. In recent years, U.S. producers exported about half of all the soybeans they produced, and sold well over half of those exports to Chinese buyers; around one out of three U.S. soybean rows is normally bound for China. As evidence of the trade war's impact, after China applied an additional 25% percent tariff to U.S. soybeans in July 2018,² U.S. census data indicate that the U.S. exported only 8.3 million metric tons (MMTs) of soybeans in 2018, compared to 31.7 MMTs over the same timeframe in 2017, a reduction of 74%.³ Notably, China did not apply that tariff to its other main soybean

¹ The United States based these trade actions on concerns over national security threats imposed by imports, and unfair trade practices. The Trump Administration has characterized the retaliation to these trade actions as "unjustified" (CRS, 2018a).

² This new tariff raised China's total tariff barrier to U.S. soybean imports to 28% (FAS, 2018) 27% (CRS, 2018b).

³ The reduction is even more significant when focusing on the July-December period. During that timeframe in 2018 China purchased just 0.8 MMT of soybeans from the United States, compared to the 22 MMT it had purchased the previous year.

vendor, Brazil. Rather, China simply substituted Brazilian for U.S. soybeans; its purchases from South America spiked following the imposition of its retaliatory tariffs (Thukral and Gu, 2018).

In response to the retaliatory tariffs directed towards U.S. agriculture, the U.S. federal government implemented a “trade aid” package to reimburse farmers for the damages they would face due to the market disruption, under powers enumerated in the Commodity Credit Corporation Charter Act. The government structured the Market Facilitation Program (MFP), a major component of the trade aid package, as a direct payment to the producers of affected commodities. U.S. producers who applied for aid could receive two MFP payments summing to \$1.65 for every bushel of their actual 2018 soybean production. The payment was not intended as a price support, but as assistance designed to help producers adjust to the new marketing landscape following China’s tariff retaliation.

We apply Carter and Smith’s (2007) Relative Price of a Substitute (RPS) method, a retrospective time series technique, to estimate that China’s trade retaliation depressed the price of U.S. soybeans for Gulf export by \$0.65/bu for the five-month period from June through November, 2018, compared to what would have been observed without the tariff in place.⁴ By December of that year, the relative price series returned to previously-observed levels, possibly due to market expectations of a trade war truce, a large new South American soybean crop in early-2019, and also perhaps to an outbreak of African Swine Fever (ASF)—a highly contagious and deadly disease for pigs that began to damage the Chinese swine population in early-August 2018 (APHIS 2019, Erickson 2018), very near the height of U.S.-China trade war tensions (Bown and Kolb 2019).

⁵ China is home to over half of the world’s pigs (FAS 2019a).

Background

Retaliation During the 2018 Trade War Targeted U.S. Agriculture

Trading partners involved in the United States' various 2018 trade disputes included China, Mexico, and Canada, three of the United States' largest agricultural export markets. According to the Congressional Research Service (2018b), China (\$20.6 billion), Canada (\$2.6 billion), Mexico (\$2.5 billion), the EU (\$1 billion), India (\$0.9 billion), and Turkey (\$0.3 billion) announced new tariffs directed at \$26.9 billion in 2017 U.S. agricultural exports, or 18% of all U.S. agricultural exports that year. The most prominent of these new trade barriers was China's 25% percent tariff on virtually all U.S. agricultural exports; of these the hardest hit was U.S. soybean products.

China is the world's largest soybean importer. Most of the soybeans it purchases are crushed and used in animal feed and cooking oil (CRS, 2018b; Qiu, Gu, and Woo, 2019). China's massive hog herd is a major source of its demand for soybeans imports.⁵ As a result, China's retaliatory tariff displaced a significant amount of U.S. soybeans from the export market. Although other trading partners like the EU, Argentina, and Egypt have purchased more soybeans from the United States than they have in the past, their additional demand did not fully offset the losses resulting from Chinese retaliation.

Possible Price and Welfare Effects of China's Tariff

If China did not enforce the tariff, or if U.S. soybeans could be transshipped costlessly through third countries, e.g., shipping them first to Canada and then on to China to avoid the import tax, the retaliatory tariff would have no price impact. Otherwise, assuming no transactions costs associated with altering world trade patterns, if Brazil could meet all of China's demand (at the same cost of production as the United States, so the initial market-clearing price), then China would simply buy from Brazil, and U.S.

⁵ China is home to over half of the world's pigs (FAS 2019a).

soybeans would be purchased by Brazil's former customers; again, there would be no effect on world prices or welfare.

However, if Brazil's supply schedule is less elastic (which was especially likely in the short run after June 2018, given that the bulk of country's harvest takes place between January and April), and it can't meet China's demand at the original price, then China's retaliatory tariff will alter world shipping patterns, relative prices, and world welfare (Gardner and Kimbrough, 1990). It would drive up the Brazilian export price, lower the United States' price, and increase the Chinese import price. These effects raise welfare for Brazilian and Chinese producers, who benefit from a higher price, and for U.S. consumers, who benefit from a lower price. Conversely, U.S. producers would be made worse off by the lower price, and Brazilian and Chinese consumers would be made worse off by the higher price they face.

Our empirical strategy focuses on structural breaks to the relative price of U.S. to Brazilian soybeans, so will be able to determine whether China's tariff policy (and enforcement) was binding in the short run. If it were non-binding, then there would be no change in relative price. In contrast, if the relative price were to change by the full amount of the tariff, then it implies that Brazilian and U.S. soybeans would be the same price to a Chinese buyer as they were before the tariffs. By implication, the marginal post-tariff U.S. soybean would be exported to China in this scenario. If the relative price changes by less than the amount of the tariff, then the marginal U.S. soybean found an alternative market or was put into storage.

Studies About the Impact of the Trade War on U.S. Soybean Prices

Taheripour and Tyner (2018) used a general equilibrium model to estimate that China's 25% tariff would reduce U.S. producer prices for soybeans by between 4-5% in the medium- to long-run. Zheng et al. (2018) use the Global Simulation Model (GSIM), an Armington partial equilibrium trade model developed by Francois and Hall (2009), to project that domestic soybean prices would fall by 3.9% in the short run due to the retaliatory tariff. Sabala and Devadoss (2019) develop a spatial equilibrium trade model to simulate

that China's retaliation would lower U.S. soybean prices by about 12%, and raise Brazilian prices by 8%. USDA forecasts of the season-average price received by U.S. soybean producers declined by 14% from May-September 2018, but that change was at best an upper bound estimate of the impact of the trade war. Many factors influence domestic commodity price levels, and good harvests in both the United States and Brazil during 2018 contributed to the weakening of each country's export prices over the course of the year.

African Swine Fever Outbreak

USDA predicts that ASF-related losses to China's breeding herd will result in a substantial contraction in the country's pork output in 2019 (FAS 2019b). That contraction would also shift inwards China's demand for soybeans, thereby reducing the world soybean price. Moreover, it would reduce positive effect of the tariffs on Brazilian export prices because Chinese buyers would shift fewer purchases to Brazil. We would also expect a smaller effect on the U.S.-Brazil relative soybean price because there would be less need for costly reshuffling of U.S. soybeans to alternative markets. Put differently, the tariff reduces Chinese demand for U.S. soybeans, where ASF reduces Chinese demand for all soybeans and therefore reduces the difference between the U.S. and Brazil.

USDA's assessment of trade damages on producers

To assist producers affected by ongoing trade war damages, USDA devised the Market Facilitation Program *ex-ante*, before both the harvest for major U.S. commodities was complete, and before the full damage to U.S. exports was known.⁶ USDA's stated intention was for these payments to help producers remarket their goods; the payments could potentially cover additional transportation, storage, and spoilage costs imposed on farmers as the United States adjusts to the new marketing landscape following

⁶ In addition to MFP, the trade aid package included commodity purchases under a Food Purchase and Distribution Program (FPDP) and an Agricultural Trade Promotion (ATP) marketing program.

the disruption caused by China's tariff retaliation. The payments were not intended to operate as price supports.

To this end, USDA decoupled the payments from 2018 sales by farmers and instead based them on 2017 production. Specifically, USDA projected MFP payment rates based on its assessment of gross "direct trade damage," or export losses to each retaliatory partner as result of additional tariffs imposed during the trade war, using a version of the GSIM (USDA 2018c). To arrive at the trade damage resulting from export-partner retaliation, USDA used GSIM to estimate 2018 export values for the threatened commodities, with and without the tariffs in place, and differenced them. Then USDA divided these trade damage values by 2017 crop year production values to arrive at a per-unit MFP payment rate, which was disbursed over two separate tranches. USDA set its total MFP payment rate for each bushel of 2018 soybeans harvested in the United States (by eligible producers) at \$1.65.

Methods and Data

Exploiting the Substitutability of U.S. and Brazilian Soybeans

Carter and Smith (2007) show that deviations in the relative price of substitute goods can be used to identify the price impact of an event that disrupts a stable market equilibrium. They introduced the relative price of a substitute (RPS) method, relying on the demand substitutability of sorghum and corn to measure the effect of the StarLink food scare on the prices of both commodities in 2000. In a trade context similar to ours, Schmitz (2018) used RPS to measure the impact of China's 2013-2014 embargo of North American corn exports on Canadian corn producers. RPS isolates price impacts of changes in relative preferences or technology, and has several advantages over other approaches, so we use it measure the impact of China's 2018 retaliatory tariff on the price of U.S. soybeans. These advantages include that RPS enables estimation of the time at which the trade war began to influence soybean prices, it is insulated from income shocks as well as demand or supply-side innovations that affect both goods equally, and it avoids specification errors associated with a full structural supply and demand system. RPS involves three

steps: (1) the presence of a stable relative price before the event, (2) a break in that relationship around the event, and (3) using a forecasting model that uses the pre-event relationship to estimate the average forecast error following the break.

To satisfy the first step, for any two substitutes RPS requires a stable pre-event relationship of the form

$$(1) \quad \ln P_{1t} - \ln P_{2t} = \mu + \beta' Z_t + u_t$$

implying that u_t is a stationary disturbance term, and supply and demand shifters in Z_t only need to be included if the log price difference between substitute goods is itself not stationary. A stable relative price implies that departures of the relative price from its mean (conditional on Z_t) correct in the long run, so that u_t is stationary. Significance of a given event's price impact is tested by searching for shifts in μ .

Like Carter and Smith (2007), we apply RPS to exploit the long-run relationship between prices for close demand substitutes: U.S. and Brazilian soybeans. In response to U.S. tariffs on Chinese goods, the Chinese government imposed a 25% tariff on U.S. soybeans (both nations announced tariff lists on June 15th, and imposed tariffs on July 6th). China is the world's dominant importer of soybeans, purchasing most of the soybean exports from the world's two dominant exporters, the United States and Brazil. China's 25% retaliatory tariff is clear candidate for an event that shifts consumer preferences, so we test for its suitability under step (2) by searching for structural breaks in the relative price of U.S. and Brazilian soybeans: $\ln P_{US,t} - \ln P_{Br,t}$.

Testing for Structural Breaks

Following Carter and Smith (2007), and because we require no Z_t variables for our application, we apply Bai and Perron (1998) tests for multiple unknown structural breaks in the mean of the log difference of U.S. and Brazilian soybean prices. Bai and Perron tests compare the maximum F statistic, or *sup-F*, over all possible break points in the sample. First, we use a sequential approach to identify individual structural breaks in the relative prices, testing each additional break against the null hypothesis of one fewer. Next,

we verify the robustness of those findings using a double-maximum test, which evaluates the null hypothesis of no structural breaks against the alternative of some unknown number of breaks up to a maximum of M .

Estimating Price Impacts

If the pre-event relationship is stable, and can be represented with a (1,-1) cointegrating vector, then we can form an error-correction model (ECM) (Engle and Granger, 1987) to forecast how post-event prices would have behaved if the pre-event relative price relationship had held:

$$(2) \quad \begin{aligned} \Delta \ln P_{US,t} &= \alpha_{US} \omega_{t-1} + \gamma_{US}(L) \Delta \ln P_{US,t} + \delta_{Br}(L) \Delta \ln P_{Br,t} + \varepsilon_t \\ \Delta \ln P_{Br,t} &= \alpha_{Br} \omega_{t-1} + \gamma_{US}(L) \Delta \ln P_{US,t} + \delta_{Br}(L) \Delta \ln P_{Br,t} + \varepsilon_t \end{aligned}$$

where $\gamma_{US}(L)$, $\delta_{Br}(L)$, $\gamma_{Br}(L)$, and $\delta_{US}(L)$ are polynomials described by the lag operator (L), and the error-correction term is $\omega_t = \ln P_{US,t} - \ln P_{Br,t} - \mu$. In our example, we use the ECM to forecast log soybean prices in both the United States and Brazil, and compare those forecasts to the actual realized values. The impacts PI_{US} and PI_{Br} of the event on the respective U.S. and Brazilian soybean prices equal the mean forecast error from the ECM over the relevant time period. Together, the ECM and the breaks testing procedure imply that $PI_{Br} = PI_{US} - \Delta\mu$, where $\Delta\mu$ denotes the change in the mean relative price caused by the event. We estimate PI_{US} as the weighted forecast error for the ECM over the 102 trading days from 6/28/2018 through 11/26/2018, and we estimate PI_{Br} as $PI_{US} - (-0.17)$, where the latter is the change in the mean relative price that we estimate was caused by the trade war. As described by Carter and Smith (2007), we calculate weights based on the variance of model forecast errors—which are heteroskedastic and correlated—by applying the ECM to the pre-break data.

Data

We use daily cash bids at export locations in both the United States and Brazil. Our U.S. prices are drawn from export elevator bids at the Louisiana Gulf, as reported by the USDA Agricultural Marketing Service.

Our Brazilian price series is collected by the Brazilian Center for Advanced Studies on Applied Economics (CEPEA) at Paranaguá port warehouses that load ships for export. Our period of observation runs from January 2015 until February 2019.

Results and Discussion

Relationship between U.S. and Brazilian Soybean Prices

Figure 1A plots the log of both series from 2015-2019. Until mid-2018, the U.S. and Brazilian soybean prices moved together quite closely. This is intuitive since both countries compete heavily for export opportunities, especially in Asia. However, coinciding with rising trade tensions and especially just before both sides imposed tariffs, U.S. soybeans at the Gulf of Mexico began to attract substantially discounted bids relative to their Brazilian counterparts. This is also evident in the log price difference displayed in Figure 1B.

Table 1 shows evidence of pre-tariff price stability. Augmented Dickey-Fuller tests are unable to reject the null hypothesis that each individual log price series contains a unit root. However, the differenced series is found to be stationary so we conclude that the two log soybean prices are cointegrated. The Johansen tests in table 1 verify the robustness of that result.

The Bai-Perron tests in Table 2 indicate that the relative price series exhibits three structural breaks over the period of interest. The most important from the perspective of this paper is the break discovered in late-June 2018, which occurs shortly after both the United States and China publish revised 25% tariff lists on June 15th, signaling their strong intentions to pursue trade barriers for \$34 billion worth of goods traded in both directions, and President Trump's June 18th request that the U.S. Trade Representative identify an additional \$200 billion of goods to tariff at 10% (Bown and Kolb, 2019). The timing of this break is also one week before the 25% tariffs on \$34 billion of goods were officially imposed by both nations. The second break identified by the sequential Bai-Perron tests occurs in late-November 2018, just as the leaders of both countries agreed to a trade war "truce" during a G20 meeting (Lander, 2018; Xin, 2018). The final

break we identified via Bai-Perron tests occurred in August, 2015. For robustness, we verified that the double maximum test rejected the null of no break against the alternative of some unknown number of breaks up to a maximum of six.

The break in late June 2018 implies a decline in the relative price of 17%, which is less than the 25% tariff, and thus implies that U.S. producers were able to find alternate markets for soybeans, either by re-shuffling exports, increasing domestic consumption, or increasing storage. Relative soybean prices returned to their pre-tariff level just as the trade war truce was called in late November, 2018, indicating the importance of trade-war expectations to the relative price series. By December, state-run Chinese firms began making commitments to purchase U.S. soybeans (Reuters, 2018). In addition, news of the large Brazilian soybean crop in early 2019 (a supply response to the retaliatory tariff), a higher-than-expected Brazilian exports forecast, and possibly ASF-driven demand side effects in China may have played a part in eroding the premium that Brazilian soybeans enjoyed beginning with the onset of trade war tensions in June, 2018.

Measuring the Price Impact of the Trade War

Figure 1B imposes the regime means identified in the structural break procedures over the log relative price series from 2015-2019. Clearly the structural break associated with the trade war had a meaningful impact on market preferences. Taken together, our stationarity results and structural break findings suggest that RPS conditions (1) and (2) are met. We therefore construct an ECM using the pre-event price data from the Aug. 2015 – Jun. 2018 sub-period in order to generate price forecasts to use in quantifying the soybean price impact of the trade war.

Table 3 presents our error-correction model results. The adjustment parameters α for each equation represent the response of the respective log prices to deviations from the long-run relationship. For U.S. soybean prices, the adjustment parameter in the table is negative but not significantly different from zero.

For Brazilian prices, α_{Br} is estimated at 0.03 and for U.S. prices, α_{US} is estimated at -0.01. Therefore, Brazilian prices bear the burden of adjustment following deviations from the equilibrium relative price in the pre-tariff period. That is, when the relative U.S. price is too high, i.e., $\ln P_{US,t} - \ln P_{Br,t} > \mu$, the Brazilian soybean price tends to rise by three times as much as the U.S. price drops; when the spread is too low, the Brazilian price tends to fall by more than the U.S. price rises. These responses re-establish the long-run relationship. Because its coefficient represents a log change and is small, it can be interpreted as a percentage. So, we take Table 3 findings to indicate that, on average, the Brazilian price adjusts at an approximate rate of 3% per day and the U.S. price by 1% per day to correct any deviation.

Figure 2 shows the errors for log price forecasts generated using the ECM. As expected, the pre-tariff data suggest that U.S. soybean prices fell and Brazilian soybean prices increased as a result of China's tariff retaliation during the trade war. We estimate that China's retaliatory tariff decreased U.S. export prices by about 7.1% (with a standard error of 0.7%), and raised Brazilian prices by about 9.5% through late-November 2018. Our finding for the reduction in U.S. soybean caused by the tariff is higher than the 4-5% price losses forecasted by both Taheripour and Tyner (2018) and Zheng et al. (2018), and lower below the 12% reduction simulated by Sabala and Devadoss (2019).

Combining our findings regarding log prices with the price of soybeans in both countries on the day before the late June structural break implies that the preference changes induced by the trade war depressed U.S. soybean prices by about \$0.65/bu (with a 95% confidence interval ranging between -\$0.52 and -\$0.78 per bushel) on average for the five months until the G20 truce was called, while raising Brazilian prices by about \$0.95/bu (with a 95% confidence interval ranging between \$0.81 and \$1.10 per bushel). Our U.S. price impact is lower than the total USDA soybean MFP payment to eligible producers in 2018. Because the latter was intended to compensate for adjustment costs that U.S. producers face in adjusting to the new marketing landscape during the trade war, this difference could perhaps be rationalized as the

reimbursement for additional transportation, storage, and spoilage costs, outside of the immediate price effects caused by the trade war.

Trade War Effects in Context

The significance and direction of our estimated price effects indicate that Chinese retaliatory tariffs were effective, at least to the extent that they were enforced on America exports and that transshipment was not costless. The observed break in the relative prices series dated to the time frame around tariff implementation, characterized by depressed U.S. prices compared to prices of Brazilian exports, indicates that Brazilian supplies were not sufficient to meet Chinese demand at the previous market-clearing price. As a result, China's retaliatory tariff altered worldwide trade patterns and lowered world welfare. Beyond reducing U.S. prices, at least in the short run U.S. adjustment to the new trade patterns was not instantaneous. As shown in figure 3, despite a record harvest the United States' total soybean exports during the 2018/19 marketing year are, as of this writing, down 28% compared to their average over the previous three marketing years. Chinese purchases of U.S. soybeans fell by over 80%, while the rise in demand from alternative export destinations like the EU was not sufficient to fully offset the difference. Many of these displaced U.S. imports found their way into storage facilities, potentially placing downward pressure on prices of future domestic soybean harvests. USDA projects U.S. ending stocks at over 1 billion bushels for both the 2018/19 and 2019/20 marketing years, more than double the level they were in 2017/18 (USDA, 2019), and also more than double the 0.4 billion bushels the Department projected for 2018/19 in the May before the trade war began (USDA, 2018d).

Conclusion

In its retaliation to U.S. tariffs during the 2018 Trade War, China targeted U.S. agriculture. American soybean exports are highly sensitive to trade disruptions, especially from China—the world's dominant importer—since in normal years about one of every three rows harvested by U.S. farmers is purchased by

Chinese buyers. The 25% retaliatory tariff China levied on U.S. soybean exports shifted market preferences so that Chinese buyers favored Brazilian soybeans. We use the RPS method to estimate that the resulting trade disruption effectively drove a wedge into the world soybean market, lowering U.S. prices by \$0.65/bu on average for about five months, and increasing Brazilian prices by about \$0.95/bu, compared to what would have been observed without the tariff in place.

By December 2018, U.S. and Brazilian prices returned to their previous relative level—a finding confirmed by our structural break tests. Erosion of the Brazilian premium initially generated by the tariff was likely due to indications ahead of the G20 meeting that the trade war would not be permanent, adjustments to the world production and trade flow in the form of expectations about a large Brazilian soybean crop by early 2019 (a supply response to the trade war tensions) and higher-than-expected Brazilian export forecasts, and possibly the effect of ASF on China's demand for hog feed.

The impacts we measure are on price bids at export locations, but it is likely that the impact of China's tariff on producers and purchasers of soybeans across the United States was heterogeneous and affected by local factors like transportation infrastructure, storage capacity, and crush facility proximity. In future work, we intend to explore the impact of the trade war on the various components of the U.S. soybean supply chain, and extend the RPS framework to other commodities affected by new retaliatory trade barriers, in order to measure the comprehensive impact of the trade war on U.S. agricultural commodity markets.

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Table 1. Pre-Tariff Tests for Cointegration

	Test Statistic	5% Critical Value	Conclusion
<i>Augmented Dickey-Fuller Tests</i>			
Log U.S. soybeans	-2.80	-2.86	Unit Root
Log Brazilian soybeans	-2.19	-2.86	Unit Root
Log relative price	-3.75	-2.86	Cointegration
<i>Johansen Test for Cointegration</i>			
Log prices have one Coint. Equation	22.9	20.3	At least one Coint. Equation
Log prices have two Coint. Equations	3.3	9.2	One Coint. Equation

Note: All tests contain an intercept and a two lags. The sample period is Jan 2015 - May 2018.

Table 2. Bai-Perron Tests for Breaks in the Cointegrating Relationship

Test	Statistic	5% Critical Value	Date of maximal F-Statistic	Conclusion
UDmax	107.3	10.17	-	# breaks $\in \{1, 2, 3, 4, 5, 6\}$
WDmax	165.9	10.91	-	# breaks $\in \{1, 2, 3, 4, 5, 6\}$
sup-F(1 0)	22.8	9.63	6/29/2018	At least 1 break
sup-F(2 1)	28.8	11.14	11/26/2018	At least 2 breaks
sup-F(3 2)	20.9	12.16	8/12/2015	At least 3 breaks
sup-F(4 3)	9.8	12.83	9/4/2018	3 breaks

Note: Maximum number of breaks set to six and minimum regime size to 5% of sample. Robust standard errors with AR(1) prewhitening used for all tests (Bai & Perron, 1998). Sample period is Jan. 2015 - February 2019.

Table 3. Pre-Trade War Error Correction Model Estimates

<i>Parameter</i>	U.S. Soybeans	Brazilian Soybeans
μ		0.01 (0.01)
α	-0.01 (0.01)	0.03 (0.01)
γ_1	-0.04 (0.04)	0.26 (0.05)
γ_2	-0.03 (0.04)	0.11 (0.05)
δ_1	0.10 (0.04)	-0.25 (0.04)
δ_2	0.01 (0.04)	-0.05 (0.04)
<i>Diagnostics</i>		
Error S.D.	0.01	0.01
Log Likelihood	4494.68	
Autocorrelation	7.17	
(p-value)	-0.21	

Note: Sample period is Aug. 2015 - Jun. 2018. Estimation by maximum likelihood. Results of Portmanteau test for autocorrelation reported as adjusted Q-statistic.

Figure 1A. Log Soybean Prices, 2015-2019

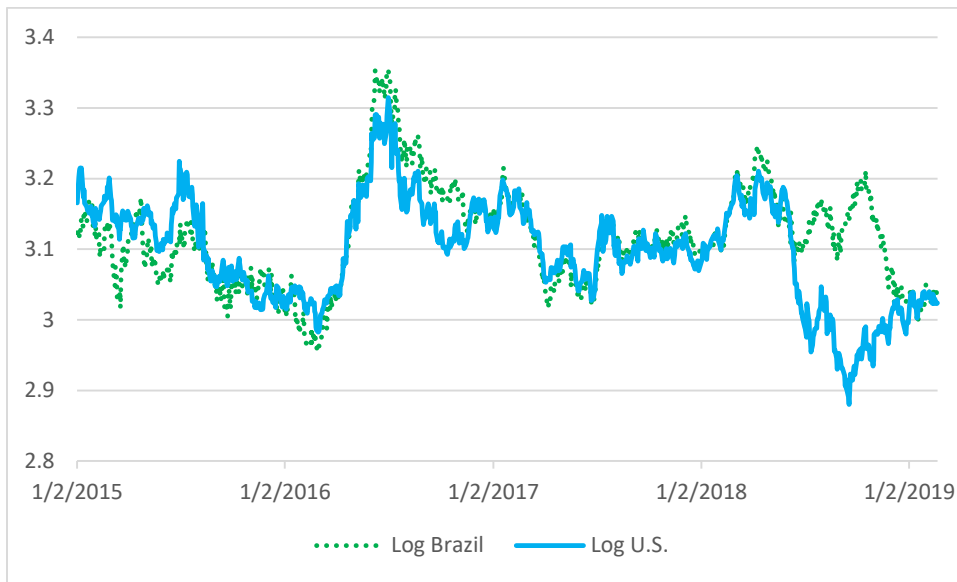
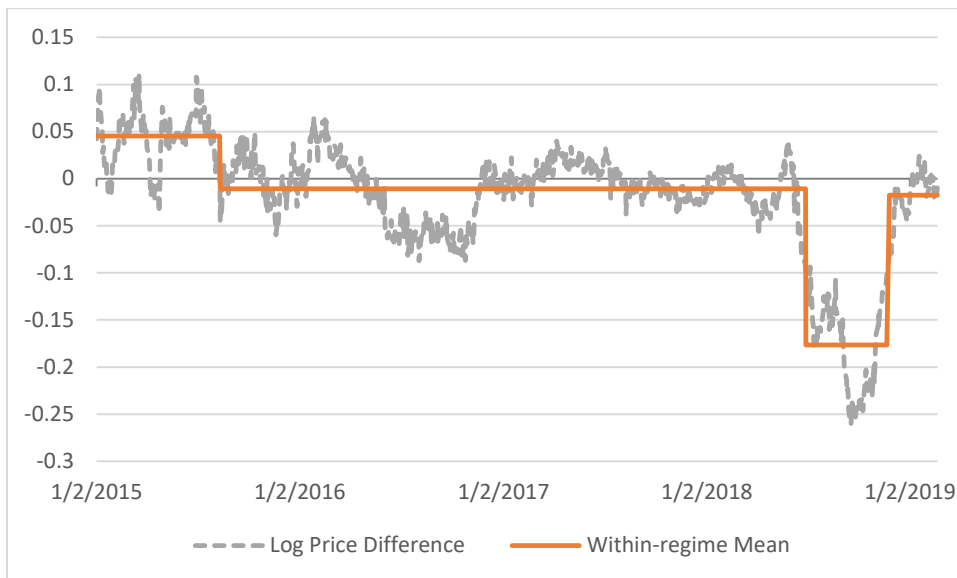
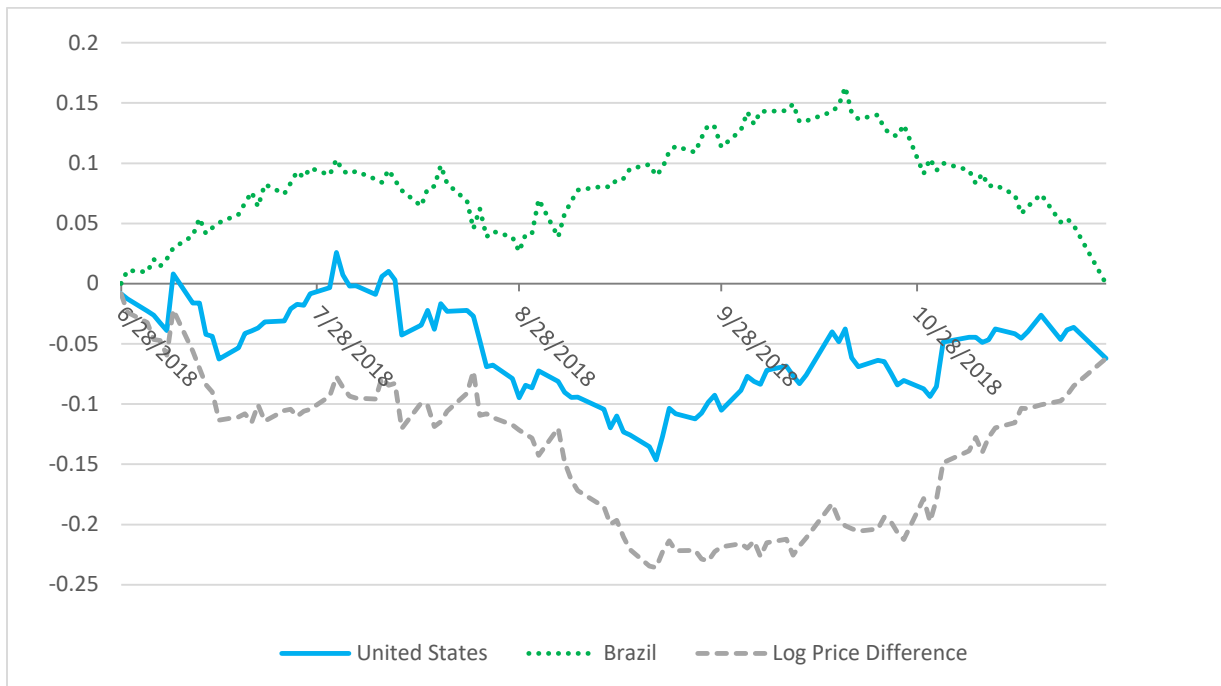


Figure 1B. Relative Soybean Price (US-Brazil), and Structural Breaks in the Series



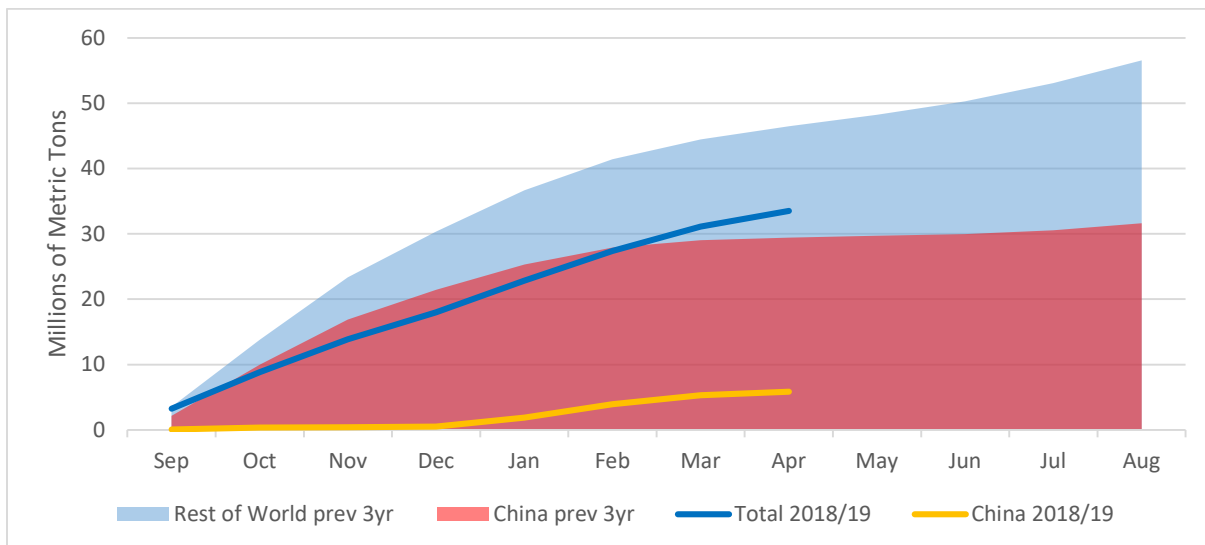
Notes: U.S. prices are drawn from export elevator bids at the Louisiana Gulf as reported by the USDA Agricultural Marketing Service. Brazilian prices are bids collected by the CEPEA at Paranaguá port warehouses that load ships for export. Units for both series are the logarithm of \$US per 60-kg.

Figure 2. ECM Price Forecast Errors During the Trade War



Notes: Errors in the chart measure actual minus forecasts for all series over the period after the 6/29/2018 structural break up to the 11/26/2018 structural break identified in Table 2.

Figure 3. U.S. Soybean Exports, Cumulative by Month During the Marketing year, by Destination



Notes: Author calculations based on U.S. census data