US-China trade war spillovers: causal evidence from the Brazilian soybean export premium

Abstract. Using the 2018 US-China trade war as an exogenous source of variation in future and spot soybean prices, we estimate the causal impact of the bilateral conflict on soybean export premiums in Brazil (port of Paranaguá), the world's largest commodity producer. Synthetic control estimates with different counterfactual groups indicate that the trade war had a positive and relevant impact on soybean export premiums in Brazil, estimated at 44.7 USD/ton (2.68 USD/bag) or 122 cents/bushel. Taking into account Brazil's total soybean exports during July-November 2018 (32.9 million tons), we estimate a direct economic impact of USD 1.47 billion [between 0.987 and 1.990 USD billion]. The findings are robust to alternative time windows around the intervention and several placebo tests. Our research quantifies trade war spillovers and helps policymakers understand the unintended consequences of bilateral sanctions and trade wars.

Keywords: US-China Trade war; Soybean price premium; Synthetic Control; Trade war spillovers.

JEL Classifications: Q17, Q02, Q14, Q18.

1 Introduction

Soybean is one of the major crops in Brazilian agribusiness. National Supply Company (Companhia Nacional de Abastecimento – CONAB, 2022) illustrates that oil seed production in Brazil experienced an extraordinary expansion from 38.4 million tons in the 2000 crop to 140.7 million tons in 2021, representing an approximate increase of 260%. Furthermore, data from the Foreign Trade Secretariat (Secretaria de Comércio Exterior - SECEX, 2022) reveal that the volume of soybean exported increased from 11.5 million to 86 million tons in 2021, indicating a remarkable increase of nearly 650% in the 21 years. As a result of this drastic growth in the last few decades, the World Agricultural Supply and Demand Estimates (World Agricultural Supply and Demand Estimates – WASDE, 2022) report that Brazil became the world's leading soybean producer in 2021 (38%), followed by the United States (31%) and Argentina (13%).

There are several explanations for the expansion of production and the increased participation in the international soybean market. First, China's demand for oil seed should be taken into account. China is the leading soybean importer worldwide and 60% of these imports came from Brazil in 2021 (Secretaria de Comércio Exterior - SECEX, 2022, World Agricultural Supply and Demand Estimates – WASDE, 2022). Second, studies demonstrate the low supply elasticity of soybeans in the United States, indicating its inability to fully satisfy the growing Chinese demand (Kim and Moschini, 2018). Finally, Brazil is advantaged in terms of the endowment of natural resources, which allows it to broaden the soybean production boundary without exhibiting significant productivity losses (the "miracle of the Cerrado" – see discourse in (Gale et al., 2019) and (De Maria et al., 2020)).

Due to its commercial importance, soybean has been the subject of political controversy. In 2018, the United States imposed tariffs on a large number of Chinese goods, which prompted China to impose retaliatory tariffs in the form of 25% tariffs on US soybean exports, starting on July 06, 2018 (Adjemian et al., 2021). This tariff war shifted the market away from US soybean producers, with Brazil taking the largest share of the lost market (Sabala and Devadoss, 2019).

Indeed, for Brazil, this trade war meant a growth of soybean exportation to China by almost 65% (from 19.7 million tons between July and December of 2017 to 32.6 million tons between July and December of 2018, see Secretaria de Comércio Exterior - SECEX, 2022). On the other hand, US soybean exports to China decreased to only 0.6 million tons compared to 22 million tons during those months in 2017 (Adjemian et al., 2021).[1]

Despite the considerable evidence in the literature suggesting that trade tensions between the United States and China have resulted in increased soybean production and prices in Brazil (Adjemian et al., 2021, Janzen and Hendricks, 2020, Sabala and Devadoss, 2019), the potential influence on export premiums has not been explored. In particular, the trade war

[1] In 2018, the United States exported 8.2 million tons of soybeans to China, compared to 31.7 million tons in 2017 (-74%) Adjemian et al. (2021). In turn, Brazil exported 65.5 million tons of soybeans to China in 2018, compared to 53.8 million tons in 2017 (+27%) (Secretaria de Comércio Exterior - SECEX, 2022).

directly impacts the operations of Tradings (e.g., Archer Daniels Midland (ADM), Bunge, Cargill, and Louis Dreyfus Company), entities responsible for the marketing of soybeans, facilitating the transportation of soybeans harvested in Brazil to Chinese ports. For these companies, the US-China trade conflict affects the formation of export premiums. Because trades act as buyers (from farmers and cooperatives) and sellers (to companies in consuming nations) at different stages of the supply chain, their performance is not dependent on the global price of soybeans, but rather on the price differences between various locations, qualities, or delivery schedules (Blas and Farchy, 2021). This underscores the importance of factors such as export premiums for the operational success of these trading companies.

The Chicago Board of Trade (CBOT) represents the international reference price for soybeans. When soybeans are shipped from, say, Brazil, their price is usually negotiated relative to this futures market price. The final price includes a premium or discount that varies among ports, connecting CBOT quotations to specific global markets (Gale et al., 2019, Moraes, 2002). In Brazil, the Paranaguá Port is the reference for soybean exports.

To assess the causal effect of the US-China trade war on the Brazilian soybean export premium, we use the Bayesian synthetic control method proposed by Brodersen et al. (2015). This approach has two primary advantages over alternative methods such as difference-in-differences: it provides a fully Bayesian time-series estimate for the effect of an intervention and uses model averaging to construct an optimal synthetic control for modeling the counterfactual. Furthermore, we follow Adjemian et al. (2021) and differentiate pre and post-trade war periods based on the date the US imposed tariffs on Chinese imports of nearly 34 billion USD (June 15, 2018)[2]. Our counterfactual is based on a set and subsets of trade-war plausibly unaffected variables, such as climate, selected macroeconomic indices, and selected commodity prices and premiums.

The outcome of interest in the empirical analyzes is the soybean export premium (estimated at Paranaguá Port), which reconciles the Chicago (CBOT) quotation and the price received by the exporter (FOB) at the Port. In particular, our estimations of the soybean export premium are based on Notícias Agrícolas (2023b) and consider the premium for spot shipment, estimated using the futures contract in CBOT that matures as closest as possible to each given day.[3] As a practical example, we estimate the soybean export premium on the 1st of March using the futures price of the contract maturing on March 15 of that given year. From March 16 onward, after that contract expires, we estimate the premium using the contract price that expires on May 15 (the next one). This procedure is performed successively in the analysis.[4].

[2]On June 15, 2018, the US tariffs on Chinese products were announced, with 06 July 2018, as the start of implementation. China retaliated with 25% tariffs on products such as US soybeans, with the same implementation date. Thus, June 15, 2018, is adopted as the pre-trade war cutoff.

[3]These contracts are usually the more liquid ones.

[4]In practice, the spot price for soybean exports on a certain date is the price in Chicago (CBOT), the future contract with the closest expiration date, add (+ or -) the premium for the spot market, which is considered the premium for the current month until the 15th of that month, shifting to the premium for the next month thereafter, and before the future contract expires (first notice day).

Our results show that the US-China trade war produced a significant increase in the Brazilian soybean export premium. All synthetic control estimates were positive and significantly different both statistically and economically: the actual premium trajectory was greater than the anticipated counterfactual in the post-event period (19.03 to 44.77 USD/Ton). Furthermore, tests simulating the causal effect on nonexistent event dates failed to yield any meaningful results, thus confirming that the trade war was the cause of the increased Brazilian soybean export premium. Beyond placebo tests, the results were also robust to different counterfactual groups.

This study expands the body of empirical literature that evaluates the consequences of the China-US trade war on the global commodity market, particularly with regard to soybeans. Previous research has revealed evidence that the trade war changed the preferences of Chinese soybean buyers and caused a break in the equilibrium relationship between commodity prices in the US and Brazil (Adjemian et al., 2021), yet no study has yet addressed the effect of the trade war on the soybean export premium. In addition, this study contributes to a better understanding of the wide range of effects caused by the China-US trade war, which have already been observed in the stock market (Chengying et al., 2021), asset pricing (Carlomagno and Albagli, 2022), spillovers to the global financial system (Minesso et al., 2022), and the economy of emerging markets (Carvalho et al., 2019).

The remainder of the document is structured as follows. Section 2 presents a review of the literature on the US-China trade war and the international soybean market, followed by methodology and data (section 3). Section 4 exposes and discusses the results of the empirical model. Finally, section 5 presents the final considerations.

2 Context and related literature

2.1 The US-China 2018 trade war

In 2018, the US Congress released a document that highlights the primary concerns of the US about trade relations with China (Morrison, 2018). This document not only criticized currency manipulation, but also addressed matters such as infringement of US intellectual property, the use of industrial policies to protect Chinese domestic industries, restrictions on foreign investment and foreign trade, lack of transparency in trade rules and regulations, economic policy distortions leading to the formation of excess capacity in several industries, and a significant trade surplus with the US. This tariff dispute further elucidates the underlying geopolitical tensions between the two countries (Pautasso et al., 2021).

Some works have sought to identify the most prominent dates and events of the trade war between the United States and China, in order to analyze its impact. As an example, Grant et al. (2021) divides the trade war into five phases: the first, from April 2018 to June 2018, which served as a preamble to the increasing tensions between the two countries; phase two, from July 2018 to December 2018, in which the conflict between them was beginning

to be considered a trade war; phase three, from January 2019 to April 2019, which saw a period of truce between the two countries, during which both sides attempted to facilitate trade discussions (including the purchase of soybeans from the United States); phase four, in which the two countries engaged in negotiations from May 2019 to September 2019, only for tensions to rise again due to the introduction of tariffs; and finally, phase five, from October 2019 to December 2019, featuring a second attempt at reconciliation between the two countries, which was marked by China's willingness to make additional purchases of American goods.

In this paper, we adopt the phase 2 mentioned in Grant et al. (2021) and presented by Pautasso et al. (2021) as the main relevant interval to evaluate the effects of the trade war on the Brazilian soybean export premium (as evidenced by Table I). In particular, this period of analysis begins on 06/18/2018, the day following the US-China tariff (and counter-tariff) announcement, and ends on 11/30/2018, marking the commencement of the trade truce between the nations, which was agreed upon at the G20 summit in Buenos Aires on December 1, 2018. This focused time frame is intended to accurately determine the impact of the trade war and to avoid any potential interference from events that occurred before or after.

[Insert Table I around here]

In the context of the trade war, Janzen and Hendricks (2020) summarize studies that analyze the impact of the trade war on soybean prices in the US, with an average reduction of 8.1% (ranging from -4 to -12%). Adjemian et al. (2021) further investigated the effects of the trade war on soybean prices in the US and Brazil. Specifically, he used a model of surrogate relative prices, and estimated that US soybean exports were reduced due to China's tariffs by USD 0.74/bu (USD 27.2/ton) in the five months, while Brazilian soybean prices in Paranaguá increased by 0.97 USD/bu (35.7 USD/ton).

According to Adjemian et al. (2021), relative prices returned to their pre-trade war levels in December 2018, as the market had adjusted to the new tariff patterns and a truce agreement had been proposed during the G20 meeting. Additionally, a large crop in South America was expected in 2019 and Chinese demand was expected to decrease due to the spread of African swine fever (ASF) in the Chinese pig herd (Adjemian et al., 2021, Gale et al., 2019).

In this context, the relevance of the second half of 2018 as a highlight of the trade war is reinforced. So, we use it - as explained above - as the relevant period to investigate the impact of this trade war on the Brazilian soybean export premium. In addition, this is a similar period used by other authors who have studied related issues, such as the impact of the trade war: on US and Brazil soybean prices (Adjemian et al., 2021), on the world's main soybean markets (Sabala and Devadoss, 2019), on agricultural exportation's (Grant et al., 2021) and on the trade aid made by American government (Janzen and Hendricks, 2020).

As seen, the second half of 2018 is a critical point of reference with regards to the trade war. Subsequently, it forms the basis of our assessment of the trade war's effect on the

Brazilian soybean export premium. This period also mirrors the one used in other research that looks into analogous topics, such as the trade war's effect on US and Brazilian soybean rates (Adjemian et al., 2021), major soybean markets around the globe (Sabala and Devadoss, 2019), agricultural exports (Grant et al., 2021), and the US government's trade aid (Janzen and Hendricks, 2020).

2.2 The evolution of the share of the US and Brazil as suppliers of soy for China

Gale et al. (2019) demonstrate that, in the mid-1990s, the United States had a 70% share in supplying Chinese demand for soybeans. Over the following years, this proportion decreased, and Brazil and the United States began to have similar proportions of Chinese imports in 2002, with each country providing 35%. This changed further in 2012-2016, with Brazilian imports accounting for half of Chinese soy imports. This number increased even more during the trade war phase 2 (July-December 2018), with Brazil comprising 77% of Chinese soybean imports and the United States dropping to just 4% (Gale et al., 2019). It is clear that the tariffs imposed by China on American soybeans triggered a shift in the export flow of the product, with Brazil being the main beneficiary (De Maria et al., 2020).

In terms of volume, Brazilian soybean imports into China increased by 81% between 2017 and 2018, from 14.2 million tons to 25.7 million tons (Gale et al., 2019). On the other hand, imports from the US soybeans experienced a sharp decline of 89% during this same period, from 24.4 million tons to only 2.7 million tons.

It should be noted that, if the cost of soybean exports to China were equivalent across both countries and Brazil was able to meet the Chinese demand in full, then US imports would have no effect on Chinese procurement and prices would not fluctuate. However, if the Brazilian soybean supply is more inelastic, which is likely in the short term due to the different harvest periods of each nation (Brazil's period runs from January to April), then Chinese demand could not be met immediately and the imposition of tariffs would alter the structure, schedule of shipment and pricing of the global economy (Adjemian et al., 2021).

Although the increase in soybean prices could be beneficial to Brazilian soybean producers, persisting at high levels could be detrimental to other participants in the supply chain, such as firms where soybeans are utilized as an input (e.g. in livestock feed). Moreover, even for soybean producers, investment decisions may not be profitable if tariffs are revoked. The uncertainty concerning the magnitude and duration of tariffs can also weaken the long-term competitiveness of Brazilian suppliers (De Maria et al., 2020). Lastly, it is essential to emphasize that the focus of this work is the Paranaguá–Chicago spread price for soybeans. However, analyzing the macroeconomic impacts on soybean derivatives, such as soybean meal and oil, could also be of importance.

3 Methodological Aspects

3.1 Empirical strategy

3.1.1 The synthetic control method

To investigate whether the outbreak of the US-China trade war had a causal impact on the soybean export premium in Brazil, we employ a particular case of the synthetic control method first introduced by Abadie and Gardeazabal (2003). In a nutshell, traditional synthetic control models use weighted averages of a pool of control units to create a synthetic control representation for the treated unit (in our setting, the soybean export premium). The approach assumes that the control units are similar to the treated unit prior to the intervention on the outcome and other relevant factors. Therefore, the donor pool that generates the counterfactual is generally composed of unities (e.g., unaffected states or countries) that are similar to the treated unit in several dimensions but differ in the sense that they did not receive shock or intervention.[5]

An alternative, more recent synthetic control approach is proposed by Brodersen et al. (2015), to estimate the counterfactual consequence of an intervention within the framework of a Bayesian structural time series model. This approach uses control variables and time-varying factors to derive the counterfactual outcome. Such an approach is especially suitable when the researcher does not have cross-sectional variation in the outcome variable – i.e., the Y variable is not observed for different individuals, which is precisely our case.[6]

Briefly, Brodersen's model, "Causal Impact", is an application of synthetic control within the framework of Bayesian structural time series models. We assume that the set of control time series was not affected by the intervention and that the relationship between covariates and the treated time series, established in the pre-period, remains stable throughout the post period. More specifically, the model combines three sources of available information for building a synthetic control: i) the time series behavior of the Y variable (soybean export premium) before the intervention, ii) the behavior of other time series that were predictive of the Y variable before the intervention; iii) the prior knowledge of the model parameters – in a Bayesian framework – derived from previous studies Brodersen et al. (2015). Importantly, one needs to assume that the variables that predict the Y variable in the pre-intervention period may not be affected by the intervention. So, the composition of the donor pool is of particular interest in the analysis.

These sources of information are used on a state-space time-series model, where one component of the state is a linear regression on the contemporaneous predictors. This allows us to select from a large set of potential controls by placing a spike and a slab prior to

[5]For example, Abadie and Gardeazabal (2003) finds that the best pretreatment fit for the Basque Country's real GDP per capita uses weights of Catalonia (85%) and Madrid (15%). Abadie et al. (2010) finds that the weights that best assembled California before the 1999 cigarette tax in California ("Proposition 99") are based on Utah, Nevada, Montana, and other states.

[6]From a practical standpoint, there were just two countries that could supply China with soybeans in the necessary scale – Brazil and Argentina.

the set of regression coefficients, inducing sparsity and substantially reducing the size of the regression problem (Scott and Varian, 2014). Subsequently, we compute the posterior distribution of the counterfactual time series given the value of the target series in the preintervention period, along with the values of the controls in the postintervention period. The difference between the predicted response and the observed response during the post-intervention period yields a semiparametric Bayesian posterior distribution for the causal effect (Brodersen et al., 2015). An implementation of this approach is provided by the CausalImpact R package.[7]

3.1.2 Set of candidate predictor variables

As a robustness check, we divided the database into four separate subsets or control groups. We then defined the subset that best adhered to the premises of the methodology applied. The first group was composed of all variables under consideration. The second subset was made up of all macroeconomic variables. The third subset was constructed from all variables that were significant at 5% in the regression of all available variables, with Soybean Premium in Brazil as the dependent variable. Finally, the fourth control group was composed of all variables that were not directly impacted by the trade war. In summary, the four different control groups used are:

1. All variables included in the donors' pool – see Table A1;
2. Only macroeconomic variables;
3. Only statistically significant variables in the core pre-shock regressions – see Table III, reg #6;
4. Only covariates not directly related to soybean price, so we remove soybean meal price, soybean price in Brazil, and soybean price in Chicago.

Within each subset of donor pools, we estimate the impacts based on a counterfactual that most accurately reflects the soybean export premium before the shock. To ensure the model's assumptions are met, we use the control group composed of variables not impacted by the trade war (the fourth group) as the baseline subset for the empirical analyses. Additionally, the results are validated by accounting for seasonal variations and verifying the shock of the trade war over different periods.

A way to test if the chock is meaningful is to carry out the analysis considering a period before the really trade war and see if the impact was or not significant. This was done considering 2017 as the pre-period and the period from the beginning of January 2018 to the end of March 2018 as the fake trade-war A way to test the significance of the chock is to analyze a period before the trade war began. We chose 2017 as the pre-period and the period

[7] Available at: `http://google.github.io/CausalImpact/`.

from the start of 2018 to the end of March 2018 to simulate the trade tensions between the US and China.[8].

We also check the evolution of the trade-war impact on the Brazilian soybean exportation premium starting on June 18, 2018, and summing the impact until the end of July, end of August, and so on, until the end of November 2018, the time of declaration of a truce between the two countries. The aim was to carry out robustness and sensitivity tests of the results to validate the real impact of the trade war on the export soybean premiums in Brazil.

3.2 Data and sample

The historical series used are daily, from 03/01/2017 to 11/30/2018. This sample is divided into two parts: (i) a pre-trade war period, from 03/01/2017 to 06/15/2018, when the US imposed a 25 percent tariff on several Chinese products taking effect on July 6, 2018; and (ii) an effective trade war period, from 06/18/2018 to 11/30/2018, the day prior to the agreement of a temporary truce between the two countries. This tariff also came into effect on July 6, 2018, and China responded in kind with a 25 percent tariff on American products, including soybeans and other agricultural products.

This time range was chosen to accurately assess the effects of the US-China trade war on Brazilian soybean export premiums, as the prospects of a resolution by the end of December 2018 could influence the analysis. Moreover, various studies have also adopted similar time frames for their respective analyzes (Adjemian et al., 2021, Grant et al., 2021, Sabala and Devadoss, 2019). Furthermore, Alessandria et al. (2024) estimate the transition probabilities between trade war and non-trade war states and find that there was no increase in the likelihood of a trade war before 2018.

We analyze the Brazilian soybean export premium at Paranaguá Port (USD/ton), as reported in Notícias Agrícolas (2023b), which serves as the primary variable of this study. The premium is the average premium for the price of the spot market in Paranaguá on a given day in a given month. This data is further utilized to form a time series until the 15th day of the month, after which the next maturity price is taken into account.

The control set is constructed with 17 variables. Among them, we have variables related to soybeans, the price of different commodities, climate variables referring to rainfall in the main grain exporting ports in Brazil and Argentina, and, finally, financial and macroeconomic variables. The selection of these seventeen variables took place to allow the formation of different control groups, and the best-fitting group was chosen to analyze the results.

Specifically, control variables can be divided into four categories related to commodity prices, namely the price of corn on BM&FBovespa in USD/ton (Centro de Estudos Avançados em Economia Aplicada – CEPEA, 2023), the price of rice and wheat in Rio Grande do Sul in USD/ton (Centro de Estudos Avançados em Economia Aplicada – CEPEA

[8]We choose this period because it occurs before phase one, described by (Grant et al., 2021), as the beginning of the commercial tensions between US and China.

(2023)), and the quotation of Brent crude oil in USD/barrel (Investing (2023)). Additionally, three climate variables representing precipitation in the Santos, Paranaguá, and Buenos Aires ports in mm / day (NASA, 2023) are included. Additionally, six macroeconomic and financial variables are included, such as the exchange rate in reais/USD (Central Bank Of Brazil - BACEN (2023)), the fixed interest rate with a 12-month term structure (% p.a.), the one-day DI interest rate with a maturity of t+1 (% p.a.), the Dow Jones Stock Exchange Index, the Bovespa Index, and the Consumer Prices Index of the Fundação Getulio Vargas (% p.m.) (IPEADATA (2023)). Finally, four variables directly related to the soybean market are considered, including the price of soybean in Brazil at the Paranaguá Port in FOB USD/ton (Centro de Estudos Avançados em Economia Aplicada – CEPEA (2023)), the export premium of soybean meal in Brazil in USD/ton (Centro de Estudos Avançados em Economia Aplicada – CEPEA (2023)), the price of soybean meal in Brazil in USD/ton (DATAAGRO (2023)), and the soybean future price on the Chicago Stock Exchange CBOT in USD/ton (Notícias Agrícolas (2023a)).[9]

3.3 Descriptive statistics

Table II presents the descriptive statistics of data, consisting of mean, median, standard deviation, maximum and minimum values in three different windows. The initial table considers the whole study period (03/01/2017 to 11/30/2018), while the second and third windows consider the period before and during the trade war (03/01/2017 to 06/15/2018 and 06/18/2018 to 11/30/2018, respectively). For example, the Brazilian soybean export premium averaged 39 usd/ton during the entire study period, which increased to 77 usd/ton during the trade war period, representing a difference of 52 usd/ton, or 141 cents/bu. This increase was even more significant when considering the median (55 usd/ton): it increased from 24 usd/ton to 79 usd/ton between the pre and trade war period. The other descriptive statistics (standard deviation, maximum, and minimum) show similar behavior, indicating that the US-China trade war profoundly impacted Brazil's soybean premium.

Finally, examining the mean behavior of the potential control variables, we observe a decrease or no increase for the majority of variables between the pre-and post-trade war period (corn and rice prices, exchange rate (R$ / USD), Brazilian inflation index (IPC-S), interest rates, precipitation variables, and soybean futures price (CBOT)). An increase is observed for the remaining variables in the same comparison, albeit at a lesser magnitude than observed for the soybean premium, reinforcing the importance of analyzing the impact of the trade war on Brazil's soybean premium.

[Insert Table II around here]

The Chinese demand for Brazilian soybeans had a two-fold effect: it increased the volume imported from the country and drove up the price and premium of soybeans in Brazil. This is

[9]The sources for each of this variables are presented in more detail in Appendix A.1 - Table A1.

illustrated in Figure 1, which shows the rise in premium (at Paranaguá Port) after mid-June 2018.

As a reference, the average price of soybean per tonne rose from $29.90 in the first half of June to $80.51 in the first half of July 2018. Notably, the premium pattern continued to remain high until the first week of November 2018, when it experienced a sharp decline to the level seen in April 2018 by the end of November, yet still higher than the pre-trade war period. This reinforces the rationale of selecting the latter half of 2018 for an analysis of the influence of the trade war on the soybean premium in the Brazilian market.

[Insert Figure 1 around here]

4 Results

4.1 Causal impact considering the core counterfactual

Our baseline counterfactual comprises all possible predictor variables, excluding those related to soybeans, which are plausibly affected by the trade war. This includes other commodities (e.g. price of oil, rice, wheat, and corn), macroeconomic indicators (spot and 1 year ahead interest rates, consumer price index, and exchange rate), financial indicators (Ibovespa and Dow Jones indexes), and climate variables (precipitation in several key GPS coordinates).[10] As one can observe from Figure 2, the counterfactual fits the real soybean export premium almost perfectly in the pre-trade war period.

[Insert Figure 2 around here]

Nevertheless, as demonstrated in Figure 2, the Brazilian soybean export premium experienced a considerable uplift immediately after the US-China trade war intensified (continuous line). In contrast, the hypothetical premium stayed nearly uniform during the pre-intervention duration (c. 30 USD/ton). Unsurprisingly, the causal influence of the trade war (the difference between the observed soybean premium and the counterfactual in the post-intervention phase) was positive and significantly different from zero at the 5% level. Specifically, the difference between the observed soybean premium and the one that would have been observed in the absence of the intervention was 44.70, with a 95% interval of [29.99, 60.49].

In relative terms, these results demonstrate a 156% increase in the soybean premium, with a 95% confidence interval ranging from 63% to 361%.

[10] It includes longitude and latitude of the two main ports in Brazil for soybeans export (*Santos* and *Paranaguá*), and also in Argentina (*Buenos Aires*).

4.2 Alternative sets of candidate variables for the counterfactual

As already mentioned, the variables were divided into four subsets before defining which would be the control group most adherent to the assumptions fundamentals of the applied methodology. And as one of the division criteria, significant variables were considered at 5% of the regression performed with all variables, with the soybean premium in Brazil being the dependent variable. The following are the results of the impact of the trade war in all these cases, Table IV:

As previously discussed, the variables were partitioned into four subsets before determining the control group that was most adherent to the model's assumptions. Furthermore, one of the division criteria considered only the significant variables at the 5% level on the regression of the soybean premium in Brazil on all variables. The subsequent results of the effect of the trade war in all these scenarios are presented in Table IV.

[Insert Table IV around here]

The four control groups were then established and presented: all variables included; only macroeconomic variables; only the variables which had been significant in the main regression; and one with the series directly related to soybean removed (the price of soybean meal and soybean in Brazil and in Chicago). With these groups defined, the causal effect of the trade war on the premiums was estimated. At first, this estimation was made for the entire period of the database, from 03/01/2017 to 11/30/2018, taking into account the moment of the shock on 15 June 2018.

In Table IV, the results show a significant impact of the trade war on the premium of Brazilian soybeans across all subsets of donor variables, demonstrating the robustness of the results. Moreover, the subsets incorporating only macroeconomic variables and those including variables unrelated to soybean had similar impacts, while the subsets containing variables potentially affected by the shock to the counterfactual saw a smaller effect.

4.3 Robustness checks

4.3.1 Causal impact under different pre- and post window lengths

Table V presents the evolution of the trade war's impact on the Brazilian soybean exportation premium from June 18, 2018, to the end of November 2018, in our reference subset. It is evident that the impact is immediate, with a consistent effect of approximately 40 usd/ton in all ranges considered. This indicates that the trade war had a substantial effect on the soybean premium in Brazil during the so-called "Phase 2".

[Insert Table V around here]

4.4 Placebo tests: simulating the causal impact on random dates before the event

In another attempt to evaluate the robustness of the results, we analyze the trade war's impact on Brazil's soybean premium by employing two samples. The first sample comprises data from 03/01/2017 to 12/28/2017, representing the pre-placebo trade war period and the trade war period from January 2, 2018, to March 31, 2018 (Placebo I). The second sample includes data from 03/01/2017 to 01/31/2018 as the pre-trade war period and the trade war period from February 1, 2018, to March 31, 2018 (Placebo II). Results are shown in Table VI.

[Insert Table VI around here]

As Table VI demonstrates, the impact of an external shock prior to the trade war between the United States and China on Brazilian soybean premiums was not statistically different from zero. Moreover, the confidence interval in both cases was near zero, suggesting that the range of variation in premiums observed in the period in which the event occurred resulted from China's imposition of tariffs on US soybeans and consequent increased Chinese demand for soybeans from Brazil.

4.5 Discussion: economic impacts of the causal effects in soybean export premiums

In addition to the statistical dimension of the trade war's impact on Brazilian soybean premiums, it is worthwhile to consider the economic magnitude of this impact on soybean exports. As previously noted, the impact of the trade war between the United States and China was measured using the synthetic control methodology, with the fourth subset of control variables as the baseline. This increased the premium to 44.70 USD/ton [30; 60.49], or approximately 122 cents/bushel [81.62; 164.63], or 2.68 USD/bag [1.80; 3.63].

This increase in the premium represents the average value of Brazilian soybean prices, which was 384.61 USD/ton during the period of trade analysis of the US-China trade war, accounting for 11.6% [7.8%;15.7%] of the total. Moreover, the total volume of soybean exported by Brazil from the beginning of July 2018 to the end of November 2018 amounted to nearly 32.9 million tons. Consequently, the financial increase of the US-China trade war on Brazilian soybean exportation was estimated to be in the range of 1.470 billion U.S. dollars [0.987; 1.990 billion USD].

Although this impact refers only to soybean premiums in Brazil, our results are aligned with other studies that have analyzed the consequences of the trade war between the United States and China on soybean prices in Brazil. For example, Adjemian et al. (2021) calculated the impact of the trade war as an increase of 35.7 usd/ton (0.97 cents/bu) or 9.7% in soybean prices in Brazil (Paranaguá). Similarly, Sabala and Devadoss (2019) indicate that Brazil's exports to China surged 62.94% due to the trade war, resulting in a 7.70% spike in soybean

prices in Brazil. The authors further postulate that Brazil, the leading competitor to the United States in the global soybean market, is the greatest beneficiary of this trade war.

Finally, this paper has focused on the soybean export premium, but other impacts on the supply chain, such as those related to primary production, could be reasonably expected. As a result, the estimated causal impact we present is likely to be underestimated.

5 Concluding remarks

Using a fully Bayesian synthetic control method, we estimate the causal impact of the US-China 2018 trade war on the soybean export premiums in Brazil, the world's largest soybean producer. Our findings indicate that the total impact of the trade war on soybean export premiums in Brazil was approximately 122 cents/bushel (44.70 U.S. dollars/ton), conferring a monetary value of more than 1.470 billion dollars [0.987; 1.990 billion]. This effect is not only statistically significant but also economically meaningful. To the best of our knowledge, this study is the first to estimate the spillovers of the US-China trade war on soybean export premiums, providing valuable insights to policymakers about the unintended consequences of trade wars.

The US-China trade conflict, characterized by phases of tension and the imposition of tariffs by both parties, had a significant impact on the Brazilian soybean market, as evidenced by the export premiums. It is essential to examine the premium – a key mechanism of international agribusiness – to understand the factors that contribute to changes and to anticipate potential fluctuations due to macroeconomic events. Such knowledge can benefit companies operating in this sector when making decisions and taking strategic positions.

As limitations, this study focused solely on the impact of Brazilian soybean premiums. It is important to note that soybean is the raw material for two main products, meal and oil, and thus, the effect may have been felt throughout the supply chain. Future research should consider the variation of the premiums of these products or assess how the increased Chinese demand for Brazilian soybeans could cause an imbalance in the supply and demand of soybean derivatives. Furthermore, the data collection period for this work concluded at the end of November 2018, while subsequent months have seen an ongoing cycle of tensions and reconciliations between the United States and China. Therefore, it is recommended that the database should be extended to later periods.

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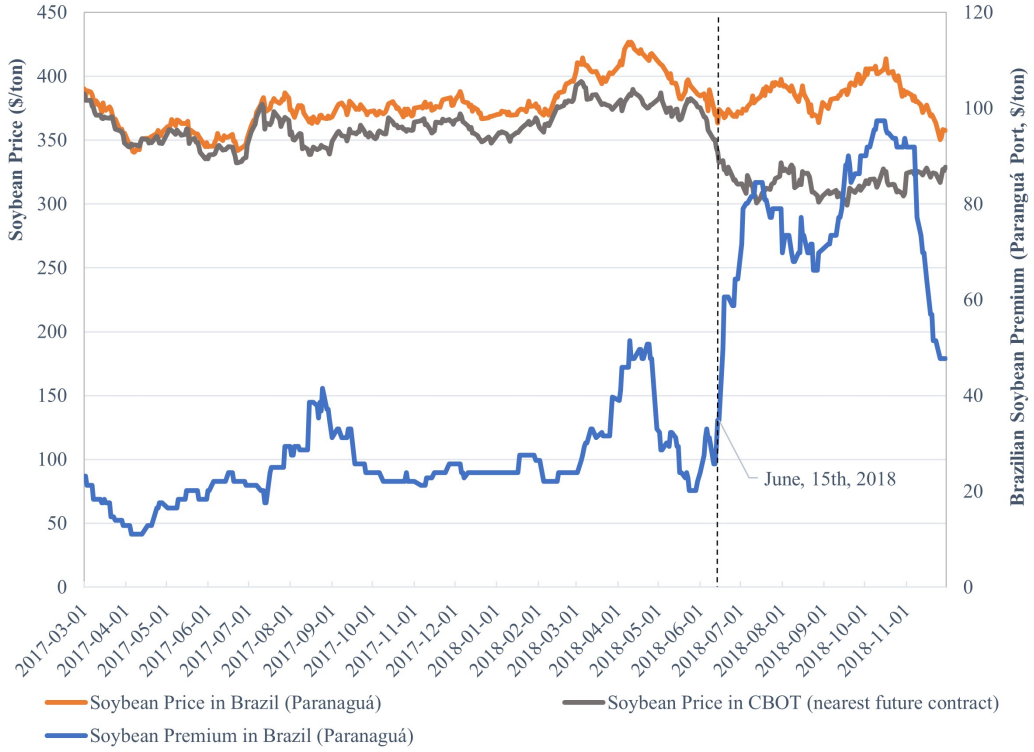
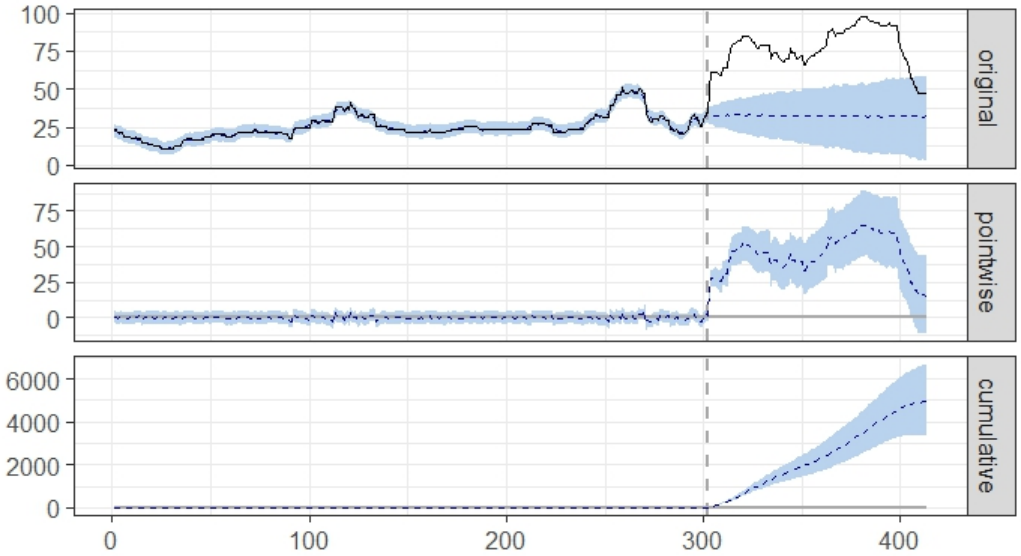
Figure 1. Soybean price in Brazil (Paranaguá) and in the United States (CBOT), and the soy premium in Brazil (Paranaguá), daily from March, 01, 2017 to November, 30, 2018.



Note: Everything is in dollars per ton.

Figure 2. Brazilian soybean export premium, real (continuous) and synthetic (dashed), before and during the trade war.



Note: central 95% credible intervals are represented in blue shaded areas.

Table I. Timetable of the Trade War between the United States and China in 2018.

Date	**Event**
July 6, 2018	US imposes tariffs on Chinese imports worth $34 billion.
July 11, 2018	The US Trade Office (USTR) releases a list of $200 billion of Chinese goods that could be subject to 10% extra tariffs.
July 20, 2018	Trump says he is "ready" to proceed with tariffs on Chinese imports worth $500 billion.
July 31, 2018	China and the US signal a restart of talks.
August 2, 2018	The US Trade Office (USTR) confirms that President Trump is considering raising tariffs from 10% to 25%, for a total increase of $200 billion.
August 3, 2018	China announces a list of $60 billion in U.S. imports and plans to apply tariffs if the Trump administration follows through with higher tariffs of $200 billion.
August 23, 2018	Second round of tariffs, which complements the US$34 billion previously levied and culminates in a total of US$50 billion.
September 17, 2018	EUA anunciam que tarifas de 10% sobre US$ 200 bilhões de exportações chinesas iniciam em 24 de setembro e permanecem até o final de 2018.
September 18, 2018	The US announces that 10% tariffs on $200 billion of Chinese exports will start on September 24 and run through the end of 2018.
September 22, 2018	China cancels trade talks with the US aimed at preventing the implementation of US$200 billion tariffs on Chinese goods.
September 24, 2018	The US implements $200 billion in tariffs on Chinese goods, bringing the total tariffs to $250 billion. China imposes $60 billion in tariffs on U.S. goods as per the list released on Aug. 3.
September 25, 2018	Chinese and US officials resume contact. Officials are preparing for Trump and Xi Jinping to meet on the sidelines of November's G20 meetings in Buenos Aires.
October 30, 2018	The US is prepared to announce tariffs on remaining Chinese goods by early December if negotiations between Trump and Xi Jinping do not result in a deal.
November 8, 2018	China and US resume trade talks.
November 18, 2018	US releases list of export controls for emerging technologies. The US Bureau of Industry and Security (BIS) publishes export control rules for technologies such as Artificial Intelligence (AI), robotics and quantum computing.
December 2, 2018	China and the US agree to a temporary truce. This truce aims to reduce trade tensions, after a working dinner at the G20 summit in Buenos Aires.

Table II. Descriptive statistics, full period and before-during the trade war

Variables	**Mean**	**p50**	**SD**	**Max**	**Min**
Panel A: Full period (03/01/2017 to 11/30/2018)					
Avg. Soybean export premium, Brazil (USD/ton)	39.3	25.7	25.0	97.4	11.0
Avg. Soybean meal export premium (USD/ton)	-11.3	-15.4	16.2	22.0	-38.6
Avg. Price Soy in Brazil (USD/ton)	378.3	376.5	17.5	426.7	340.5
Avg. Price Soy in the US (USD/ton)	348.9	354.2	23.2	395.9	299.1
Avg. Price Soybean meal (USD/ton)	330.4	321.4	32.6	405.0	270.2
Rice (USD/ton)	231.0	229.0	17.7	304.2	194.4
Cornbean (USD/ton)	165.2	163.3	19.6	219.2	128.3
Wheat, Rio Grande do Sul (USD/ton)	196.7	190.6	25.4	260.4	156.0
Oil (Brent, USD)	64.0	64.3	10.8	86.3	44.8
Exchange Rate USD/BRL	3.4	3.3	0.3	4.2	3.1
Ibovespa index	75,034	75,429	7,966	89,709	60,761
Dow Jones index	23,641	24,264	1,866	26,828	20,404
Consumer Price Index (%, monthly)	0.3	0.3	0.3	1.2	-0.3
Interest rates - Spot	7.9	6.9	1.9	12.1	6.2
Interest rates - 1 year	7.7	7.4	1.0	10.1	6.3
Precipitation, Argentina (mm/day)	2.6	0.0	6.9	55.8	0.0
Precipitation, Paranaguá port (mm/day)	4.9	1.7	8.2	66.4	0.0
Precipitation, Santos (mm/day)	3.1	0.9	5.3	39.0	0.0
Panel B: Before the US-China trade war (03/01/2017 to 06/15/2018)					
Avg. Soybean export premium, Brazil (USD/ton)	25.3	23.9	7.9	51.4	11.0
Avg. Soybean meal export premium (USD/ton)	-17.5	-20.9	13.9	19.8	-38.6
Avg. Price Soy in Brazil (USD/ton)	376.0	374.2	18.3	426.7	340.5
Avg. Price Soy in the US (USD/ton)	360.7	358.5	13.8	395.9	332.2
Avg. Price Soybean meal (USD/ton)	323.5	309.5	34.8	405.0	270.2
Rice (USD/ton)	233.4	231.0	19.3	304.2	194.4
Cornbean (USD/ton)	165.3	163.2	22.5	219.2	128.3
Wheat, Rio Grande do Sul (USD/ton)	186.8	179.6	20.5	260.4	156.0
Oil (Brent, USD)	60.0	57.6	9.4	79.8	44.8
Exchange Rate USD/BRL	3.3	3.2	0.2	3.9	3.1
Ibovespa index	73,257	72,936	8,063	87,652	60,761
Dow Jones index	22,984	22,873	1,726	26,617	20,404
Consumer Price Index (%, monthly)	0.3	0.3	0.2	1.0	-0.3
Interest rates - Spot	8.5	7.9	2.0	12.1	6.2
Interest rates - 1 year	7.7	7.2	1.1	10.1	6.3
Precipitation, Argentina (mm/day)	2.7	0.0	7.1	55.8	0.0
Precipitation, Paranaguá port (mm/day)	3.8	1.0	7.4	66.4	0.0
Precipitation, Santos (mm/day)	2.6	0.5	5.4	39.0	0.0
Panel C: US-China trade war period (06/18/2018 to 11/30/2018)					
Avg. Soybean export premium, Brazil (USD/ton)	77.2	79.0	13.3	97.4	47.8
Avg. Soybean meal export premium (USD/ton)	5.6	5.5	8.1	22.0	-13.2
Avg. Price Soy in Brazil (USD/ton)	384.6	385.2	13.3	413.5	350.3
Avg. Price Soy in the US (USD/ton)	316.8	315.7	7.9	333.8	299.1
Avg. Price Soybean meal (USD/ton)	349.2	350.9	14.0	380.9	321.1
Rice (USD/ton)	224.2	223.4	9.7	246.6	207.0
Cornbean (USD/ton)	165.1	163.7	7.2	185.2	153.5
Wheat, Rio Grande do Sul (USD/ton)	223.5	224.3	16.6	253.7	190.8
Oil (Brent, USD)	75.0	75.3	5.8	86.3	58.7
Exchange Rate USD/BRL	3.9	3.8	0.2	4.2	3.6
Ibovespa index	79,868	78,767	5,244	89,709	69,814
Dow Jones index	25,428	25,387	689	26,828	24,118
Consumer Price Index (%, monthly)	0.4	0.4	0.3	1.2	-0.2
Interest rates - Spot	6.4	6.4	0.0	6.5	6.4
Interest rates - 1 year	7.5	7.5	0.4	8.2	6.8
Precipitation, Argentina (mm/day)	2.2	0.0	6.3	41.4	0.0
Precipitation, Paranaguá port (mm/day)	7.8	5.0	9.5	55.8	0.0
Precipitation, Santos (mm/day)	4.3	2.7	4.9	24.8	0.0

Table III. Linear Regression of Soybean Premium over all potential covariates, daily data from March-01-2017 to June-14-2018

Variable	Regression					
	(1)	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*
Cornbean (USD/ton)	0.0560***	0.0875***	0.0322	0.0304	-0.0444*	-0.0245
	(0.02)	(0.02)	(0.03)	(0.03)	(0.03)	(0.02)
Rice (USD/ton)	-0.0479***	-0.1833***	0.2074***	0.2178***	0.0314	0.0614
	(0.02)	(0.03)	(0.05)	(0.05)	(0.05)	(0.04)
Wheat, Rio Grande do Sul (USD/ton)	0.1778***	0.2787***	0.1436***	0.1400***	0.0456**	0.0443**
	(0.03)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)
Oil (Brent, USD)		-0.0767	-0.5155***	-0.5145***	-0.3134***	-0.2922***
		(0.07)	(0.11)	(0.11)	(0.08)	(0.08)
Exchange Rate BRL/USD		-28.0595***	20.8025***	22.0211***	13.5273***	8.5103**
		(3.30)	(5.70)	(5.97)	(4.33)	(4.15)
Consumer Price Index (%, monthly)			8.0583***	8.0726***	2.9225**	2.6637*
			(1.79)	(1.76)	(1.46)	(1.47)
Interest rates - Spot			0.3477	0.4071	1.3288	1.5755*
			(1.09)	(1.10)	(0.94)	(0.83)
Interest rates - 1 year			-6.8640***	-7.0860***	-0.9500	-2.8697**
			(1.76)	(1.78)	(1.49)	(1.42)
Ibovespa index			0.0006***	0.0006***	0.0005***	0.0001
			(0.00)	(0.00)	(0.00)	(0.00)
Dow Jones index			-0.0019***	-0.0019***	0.0004	0.0005
			(0.00)	(0.00)	(0.00)	(0.00)
Precipitation, Santos (mm/day)				0.0320	0.0053	0.0183
				(0.08)	(0.04)	(0.04)
Precipitation, Paranaguá port (mm/day)				0.0150	0.0223	0.0185
				(0.05)	(0.03)	(0.03)
Precipitation, Argentina (mm/day)				-0.0305	-0.0451	-0.0419
				(0.05)	(0.03)	(0.03)
Price Soybean meal (USD/ton)					-0.0332	-0.0506**
					(0.02)	(0.02)
Price Soy in Brazil (USD/ton)					0.7351***	0.6520***
					(0.06)	(0.05)
Price Soy in the US (USD/ton)					-0.6204***	-0.5271***
					(0.04)	(0.05)
Soybean meal export premium (USD/ton)						0.1915***
						(0.03)
Constant	-5.9676	97.8197***	-46.0837*	-50.6408*	-96.8892***	-52.5024**
	(7.30)	(17.56)	(25.67)	(26.52)	(23.03)	(22.03)
Obs.	302	302	302	302	302	302
R-Sq.	.37	.472	.608	.61	.826	.845
F	23.9	41.4	50.1	40.1	68	75.7

Note: *, ** and *** indicate statistical significance at the 10%, 5% and 1% levels, respectively. Robust standard errors are shown in parentheses.

Table IV. Causal impact of the trade war on the soybean export premium in Brazil considering alternative sets of candidate predictor variables

Counterfactual sets	**Trade war impact (usd/ton)**	**95% C.I.**
All candidate variables	19.03	[14.90; 23.12]
Only macroeconomic variables	44.77	[29.64; 60.89]
Only significant regressors at the 5% level	19.51	[15.88; 23.67]
All candidates but the ones related to soybean	44.70	[29.99; 60.49]

Table V. Causal impact under alternative time windows around the trade war

Pre intervention - 03/01/2017 to 06/15/2018	**Trade war impact (usd/ton)**	**95% C.I.**
Impact from June 18, 2018 to end of July 2018	41.00	[32.28; 50.21]
Impact from June 18, 2018 to end of August 2018	39.87	[29.42; 50.84]
Impact from June 18, 2018 to end of September 2018	42.29	[30.67; 54.52]
Impact from June 18, 2018 to end of October 2018	46.87	[34.06; 61.17]
Impact from June 18, 2018 to end of November 2018	44.70	[29.87; 60.36]

Table VI. Placebo tests: simulating the causal impact on random dates before the event

Pre intervention - 03/01/2017 to 12/28/2017	**Trade War impact (usd/ton)**	**95% C.I.**
Placebo I (January 02, 2018 to March 31, 2018)	1.64	[-4.89, 8.51]
Placebo II (February 01, 2018 to March 31, 2018)	0.41	[-5.72, 5.71]

A Appendix

A.1 Description and source of the variables used in this study

Table A1 shows the definition and the source of all variables used in this study.

Table A1. Description of all variables used in this study

Variable	Description	Source
Rice Price	Rice Price, Brazil/RS, (USD/ton)	CEPEA/ESALQ
Exchange Rate	Nominal exchange rate, BRL/USD	Central Bank of Brazil
Dow Jones index	Dow Jones Stock Market Index (US)	Ipeadata
Ibovespa index	Ibovespa Stock Market Index (Brazil)	Ipeadata
Consumer Price Index	Consumer Price Index, FGV (%, monthly)	Ipeadata
Interest rates - Spot	1-day DI interest rate - futures: maturity on t+1 (% p.a.)	Ipeadata
Interest rates - 1 year	Fixed interest rate - 12-month term structure (% p.a.)	Ipeadata
Corn Price	Average corn price - quotation on BM&Fbovespa (USD/ton)	CEPEA/ESALQ
Crude Oil Price	Price of a Barrel of Brent Oil (in USD/barrel)	Investing.com
Precipitation - Argentina	Precipitation in Buenos Aires, Argentina (mm/day)	NASA prediction of Worldwide Energy Resources
Precipitation - Paranaguá	Precipitation in Paranaguá - PR (mm/day)	NASA prediction of Worldwide Energy Resources
Precipitation - Santos	Precipitation in Santos - SP (mm/day)	NASA prediction of Worldwide Energy Resources
Soybean Meal Price	Average price of Soybean Meal in São Paulo (USD/ton)	Datagro.com
Soybean Price	Average Soybean Price in Brazil, FOB Paranaguá (USD/ton)	CEPEA/ESALQ
Soybean Price in the US	Average Price of Soybeans on the Chicago Stock Exchange (CBOT) (in USD/ton)	CBOT
Soybean Meal Export Premium	Soybean Meal Average Premium, spot - next-maturity contract, FOB Paranaguá (in USD/ton)	CEPEA/ESALQ and Broadcast.com.br
Soybean Export Premium	Soybean Average Premium, spot - next-maturity contract, FOB Paranaguá (USD/ton)	Notícias Agrícolas
Wheat Price	Average Wheat Price – Rio Grande do Sul (USD/ton)	CEPEA/ESALQ

A.2 Time series graphics

Figure 1. Daily vis. of the Soybean Export Premium and all variables in the donor's pool

(a) Soybean export premium, Brazil (USD/ton)

(b) Soybean meal export premium (USD/ton)

(c) Avg. Price Soy in Brazil (USD/ton)

(d) Avg. Price Soy in the US (USD/ton)

(e) Price Soybean meal (USD/ton)

(f) Rice (USD/ton)

Figure 1. Daily time series of the Soybean Export Premium and all variables in the donor's pool (cont.)

(g) Cornbean (USD/ton)

(h) Wheat, Rio Grande do Sul (USD/ton)

(i) Oil (Brent, USD)

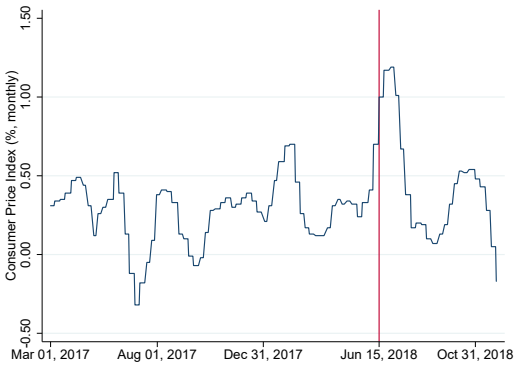
(j) Exchange Rate BRL/USD

(k) Ibovespa index

(l) Dow Jones index

Figure 1. Daily time series of the Soybean Export Premium and all variables in the donor's pool (cont.)

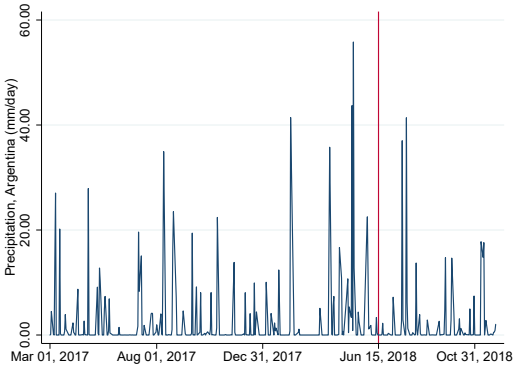
(m) Consumer Price Index (%, monthly)



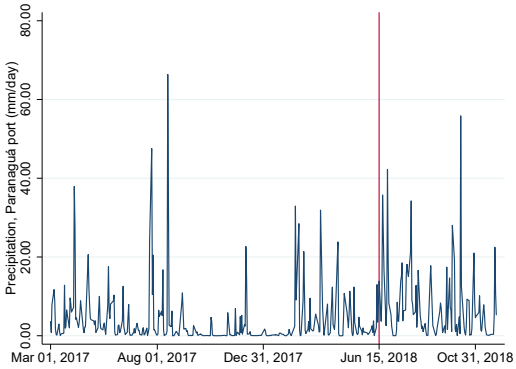
(n) Interest rates - Spot

(o) Interest rates - 1 year

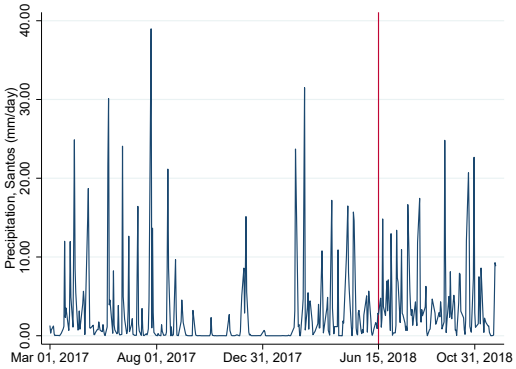
(p) Precipitation, Argentina (mm/day)



(q) Precipitation, Paranaguá port (mm/day)



(r) Precipitation, Santos (mm/day)



Note: This Figure shows the daily time series of all variables used in the study. The red, vertical line represents the day of the trade war shock (June 15, 2018).