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The Bitter Taste of Brazil's Temporary Import Ban on Robusta Coffee

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Abstract: Brazil, one of the world's largest producers and exporters of Robusta coffee can experience droughts and poor harvest and becomes a temporary importer of Robusta. The 2016-17 drought lowered Brazilian Robusta production and depleted stocks. Imports of one million 60-kg bags of Robusta coffee were temporarily allowed in the spring of 2017. An import ban was set before imports occurred, due to rent-seeking pressures of coffee farmers. We analyze the welfare and trade implications of this drought episode and coffee import ban for various actors in the Robusta bean and soluble markets. The ban increased Brazilian Robusta producers' welfare between \$174 and \$277 million nearly offsetting the impact of the drought. The ban hurt Brazilian soluble processors by raising their cost by 10% and lowered final consumers' surplus in Brazil between \$109 and \$173 million. Deadweight losses were small as these markets are price inelastic. Major Robusta exporters lost 32 to 69 thousand metric tons (tmt) of exports to Brazil and faced up to 9 % lower prices on their total exports of Robusta. Foreign consumers of Brazilian soluble coffee lost between \$62 and \$107 million of consumer welfare because of higher prices. The world price in the absence of the ban would have been 12\$/bag higher for these stakeholders. The import ban benefited Robusta buyers in the rest-of-the-world (RoW). The drought itself created large rents for the RoW net exporters of Robusta but at the cost of net importers of Robusta beans and soluble coffee, globally.

Keywords: Robusta coffee, import ban, rent seeking, drought, welfare effects, Brazil, trade, protectionism

JEL Codes: F13, Q17, Q18

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1. Introduction

Coffee is one of the most valuable and widely traded and consumed agricultural commodities. Two main types of coffee are commercially grown: *Coffea arabica* (Arabica) and *Coffea canephora* (Robusta). Robusta is mainly used in soluble coffee production and accounts for about 40% of the world's coffee supply. Brazil is one of the world's largest producers and exporters of Robusta coffee, for both beans and soluble coffee. However, droughts and poor harvests can turn Robusta beans into an importable commodity for Brazil. Brazil has restrictions in place to limit unlikely imports of coffee, although it is a competitive exporter in most years. Brazil has a long history of policy interventions and distortions in the coffee market (Bates, 1997, Baffes et al., 2005).

To illustrate with a recent event, the 2016-2017 drought in the top-producing state of Espirito Santo led to a sharp decline in national Robusta coffee production and stocks, which induced a trade pattern reversal. The government of Brazil allowed temporary imports of one million 60-kg bags of Robusta coffee beans from February through May 2017. Vietnam, the world's largest producer of Robusta, was likely to benefit directly as its Robusta coffee beans are a close substitute to Brazilian Robusta (Conillon Robusta) in soluble-coffee processing. President Temer eventually suspended the import authorization prior to the onset of imports due to rent-seeking pressure by domestic coffee farmers.

The effective import ban and high domestic price helped Brazilian coffee farmers but hurt soluble processors and final consumers in Brazil. In the meantime, major Robusta exporters, notably Vietnam, suffered from the import ban with lower exports and lower world price of Robusta coffee beans that would have been the case under the drought but without the ban. The ban may have been helpful for the RoW's Robusta coffee users and processors because of the price suppression effect of the ban which mitigated the increase induced by the drought in Brazil. Large imports by Brazil would have driven up the world price of Robusta beans. The original shock from the drought benefited competing exporters of Robusta beans and hurt consumers of beans and soluble coffee globally, especially in net importing countries.

We analyze and quantify the welfare and trade implications of the Brazilian 2016-17-drought episode and associated Robusta coffee import ban. We contribute most directly to the agricultural trade policy literature, analyzing trade restrictions and protection by competitive exporters, and to the literature specific to international coffee trade, as explained below.

The case of natural exporters imposing trade restrictions and protection occurs quite often in agriculture and related markets (e.g., Klomp and Hoogezand, 2018; Koo et al. 1994; Anderson et al. 2007; Elobeid and Tokgoz, 2008; and Beckman and Arita, 2017). It is an outcome of rent-seeking by industries to secure rents in case of shocks such as natural disasters (Klomp and Hoogezand, 2018) or to reduce competition in some sub-segment of the market to improve margins (Anderson et al., 2007). Klomp and Hoogezand find systematic econometric evidence of increasing protection increasing for exportable crops with occurrences of drought, floods, and large storms. Conventional analysis under the assumption of homogenous commodity considers these trade restrictions as nonbinding given the large excess supply leading to exports (e.g., Elobeid and Tokgoz, 2008).

These restrictions can become effective in different states of the world and lead to higher expected profits as the restrictions may become binding in case of a drought or other supply shock, or if the policy instrument allows to boost domestic prices. Some early literature (e.g., Young and Anderson (1980), and Anderson and Riley (1978)), focused on the optimal trade policy in presence of price and/or production uncertainty but abstracted from political-economy motives to distort trade. Rausser and Freebairn (1974) addressed the choice of import beef quota by US policymakers and the implicit political-economy trade-offs between producers and meat consumers and their economic efficiency consequences. Our paper is in the vein of the latter, elucidating welfare trade-offs and efficiency implications for the Brazilian and international Robusta coffee markets and the applied import ban.

Beyond coffee and more recently, Dhoubhadel et al. (2015) looked at U.S. beef import quotas and meat prices in the US. The United States is a net exporter of beef by value and limits the importation of lower quality cuts to boost US margins but hurt final consumers. The authors found that beef imports are substitutes for domestically produced beef; quotas, not surprisingly raise meat prices for U.S. consumers. In another protectionism case, Hallren and Opanasets (2018) analyze the welfare impact of removing country of origin mandatory labels (COOL) on beef products in the United States. U.S. producers lose and consumers gain from the removal of the labelling requirement, which handicaps beef imports by the United States from Canada and Mexico. Beckman and Arita (2017) also analyze the interaction of TRQs and phyto-sanitary regulations in US-EU trade flows. Other examples of exportables benefiting from trade restrictions on competing imports include the older and former U.S. tobacco program, an exportable commodity for U.S. agriculture, although its imports were subject to trade restrictions (Beghin and Chang, 1992).

Our paper further contributes to the large literature on coffee trade. That literature has focused principally on sustainability of global supply chains and fair trade (e.g., De Pelsmacker et al., 2005), and their impact on small holders in coffee-producing countries. The coffee value chain is skewed in favor of final-consumer countries and multinational corporations, as pointed out by

Talbot (1997) and Ponte (2002), at the expense of producers, mainly those in developing countries. Muradian and Pelupessy (2005) examine the impacts of participation in voluntary regulatory systems on farmers' upgrading. They conclude that it does not ensure improved economic outcomes, but it has potential to promote sustainability.

Bacon (2005) investigates the price of coffee for a selected group of 228 Nicaraguan coffee farmers and discovers that farmers who possessed Fair Trade certification experienced a notable increase in the prices they got for their coffee. The coffee growers who participated in Fair Trade earned an average payment of about twice the size of the payment received by farmers who sold conventional coffee earned ($0.84/lb, $0.41/lb). Similarly, Dragusanu et al. (2022) argue that Fair Trade certifications generate additional producer surplus, as supported by empirical evidence from Costa Rica.

Closer to our investigation, Mendes and Luchine (2020) assess the effects of removing sanitary and phytosanitary measures and technical barriers to applied to Robusta for the soluble coffee industry in Brazil. We also note the older and important contribution of Bates (1997) detailing the political economy of coffee trade policies, including in Brazil.

The contribution made in this study is first to empirically delineate the trade, price, and welfare impacts of the coffee import ban by Brazil following the drought and supply shock in 2016–17. This elucidation allows us to identify who initially lost or won with the drought and who "won and lost" from the policy interventions, hence the implicit trade-off between producer and consumers interests, an aspect that has not been thoroughly examined previously. We also look at the efficiency implication of the transfer from buyers to Brazilian producers of Robusta beans. The transfer induced by the ban was large but induced small deadweight losses. The scheme is unfair as most rent-seeking schemes are; it penalized decentralized buyers to benefit an organized lobby; but it is relatively efficient with deadweight losses amounting to a small fraction of transfers.

Additionally, our research adds to the existing body of literature on protectionist policies by explicating how trade restrictions imposed by natural exporters can have intricate consequences beyond the direct protection of domestic farmers. The impact on net exporters and importers is substantial because Brazil sets world prices, and it hinges critically on the price responsiveness of the residual world coffee market faced by Brazil.

The following section sets the stage with some background on Robusta coffee and the Brazilian coffee market which motivates important modeling assumptions. This is followed by the modeling exposition and its calibration. We then define the two scenarios and present their simulations which are then discussed. The paper concludes after that.

2. Background on Robusta Coffee and Brazil Coffee Market

Robusta coffee

Robusta coffee originates from western Sub-Saharan Africa and can be cultivated in tropical countries. It has a higher concentration of caffeine than Arabica, which makes it more resistant to disease and pests since caffeine has a toxic effect on pests and resistant to processing which tends to reduce caffeine content. Additionally, it can also resist extreme temperatures and direct sunshine. Robusta coffee beans are cultivated at a lower altitude, require less care, and generate higher yields than Arabica.

For these reasons, Robusta stands out against more vulnerable Arabica, whose maintenance costs increase with climate change and global warming and associated stresses. Robusta beans are mainly used in soluble, or instant coffee industry because of their lower cost, and the high concentration of caffeine previously mentioned. Appendix Figure 1 provides further information contrasting Arabica and. Robusta.

The global production share of Robusta coffee has experienced significant growth over the last three decades, rising from 27.5% in 1990 to 40% of total coffee production in 2020 (ICO, 2023). This increasing importance is expected to continue, given that Arabica coffee production faces more challenges and stresses from climate change. The top-five highest producing countries for Robusta are Vietnam, Brazil, Indonesia, Uganda, and India. Vietnam primarily focuses on Robusta production, whereas Brazil is known for substantial production of both Arabica and Robusta varieties.

Coffee in Brazil

Brazil has been the world's leading producer and exporter of coffee for over two centuries (Bates 1997, Government of Brazil 2022), accounting for 32% of global output and 23% of exports in 2020. Brazil exported nearly 42.4 million 60-kilogram bags of coffee beans in 2021, generating about $6.4 billion of income (Government of Brazil, 2022).

Coffee has been one of the major economic boons for Brazil throughout history. Brazil was a coffee near monopolist in the early 20th century and often attempted to manipulate the world coffee market, restricting exports to increase the world price. On the other hand, a higher world price has been inducing higher output in competing countries, and their increased output eventually undermined Brazil's market dominance (Jarvis, 2012). Brazil was also the world's largest producer of soluble coffee before falling behind Asian countries. Vietnam and Indonesia increased their global market share from near 0% and 3% in 2010 to 11% and 20% in 2016, respectively, while Brazil's declined from 22% to 13% even though its output remained almost the same (Mendes and Luchine, 2020).

Coffee production requires two years to harvest berries after planting and five years to reach optimal yield. Coffee trees can keep producing high-quality beans for another twenty years (Milford, 2004). This slow maturation process of coffee trees leads to a supply (both acreage and yield) that is extremely inelastic in prices in the short to medium term. Our modeling assumptions reflect this stylized fact.

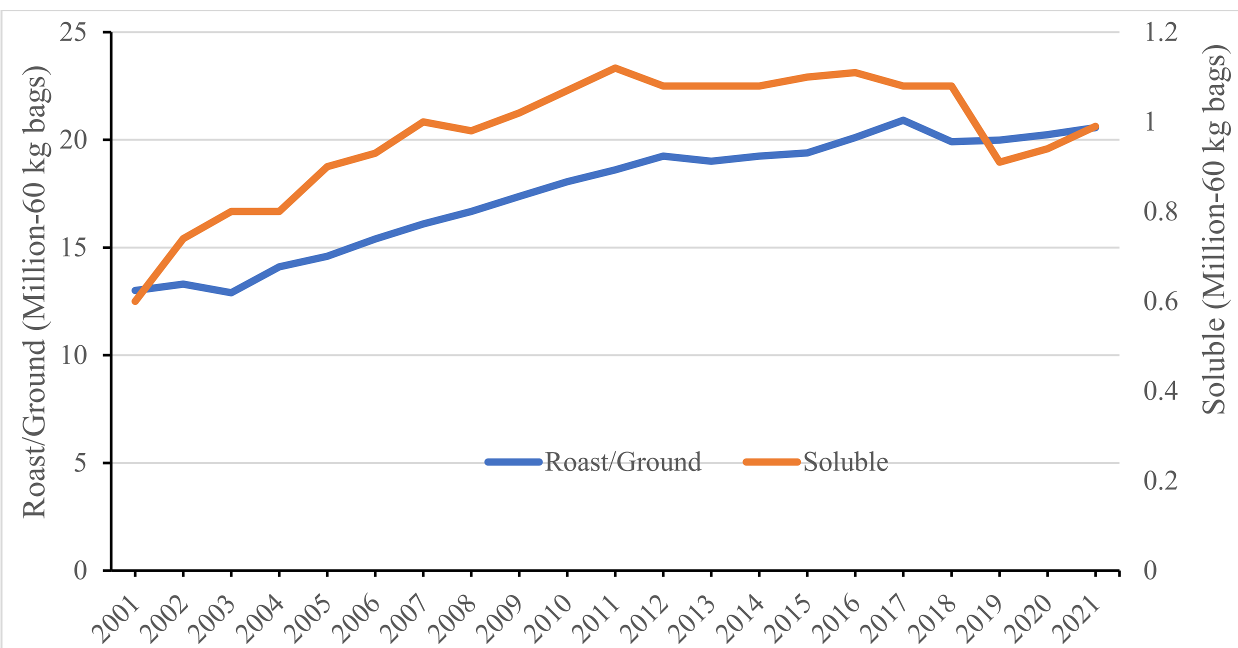
Brazil produces both Robusta and Arabica coffee. The total production of Robusta has steadily increased, except for the years that coincide with the prolonged 2014-2017 Brazilian droughts and plunged to record lows when the drought hit the top producing states of Espirito Santo and Bahia in 2016-17. However, total Arabica production has varied each year depending on the on and off year of the biannual production cycle, typical of Arabica. The coefficients of variation for 2001-21 for the two coffee productions was slightly higher for Arabica (0.220) than for Robusta (.208) reflecting the higher mean and standard deviation for Arabia than for Robusta. Aggregate production has the lowest coefficient of variation (0.192) indicating a partial offset of the variations of one production by the other's variation.

Arabica dominates Brazilian coffee production with about 70% of the coffee production while Robusta accounts for the remaining 30%. Arabica production is in the main coffee-growing cluster of states led by Minas Gerais, where it is produced almost exclusively, whereas Robusta is primarily grown in the southeastern much smaller state of Espirito Santo, where about 80% of the coffee is Robusta. Appendix Figure 2 provides further information on the distribution of coffee production by variety and by state throughout Brazil.

Although Brazil has been the world's leading coffee supplier for both Robusta and Arabica varieties, it has yet to reach the same extent of productivity as its competitors, especially in Robusta production. For instance, Vietnam produces about two times as much coffee per hectare due to their specialization in the cultivation of Robusta coffee. Moreover, with the given efficient production practices and its exclusive concentration on Robusta cultivation, Vietnam has emerged as a leading producer of Robusta in recent years, surpassing Brazil in terms of Robusta output. In 2020, Brazil produced around 20 million bags, whereas Vietnam, its largest competitor, produced around 30 million bags in the same year. Lastly, the disparity among the two competitors is that Vietnam is strategic in its effort to prioritize volume-driven Robusta production, whereas Brazil poses as a versatile competitor, striking a balance in the production of both varieties of coffee.

Brazil is the world's third-largest coffee consumer after the European Union and the United States. Total coffee consumption in Brazil has ranged between 20 and 22 million bags over the last decade. Ground coffee accounts for around 95% of overall consumption, with soluble coffee accounting for the remaining 5%. (See Figure 1).

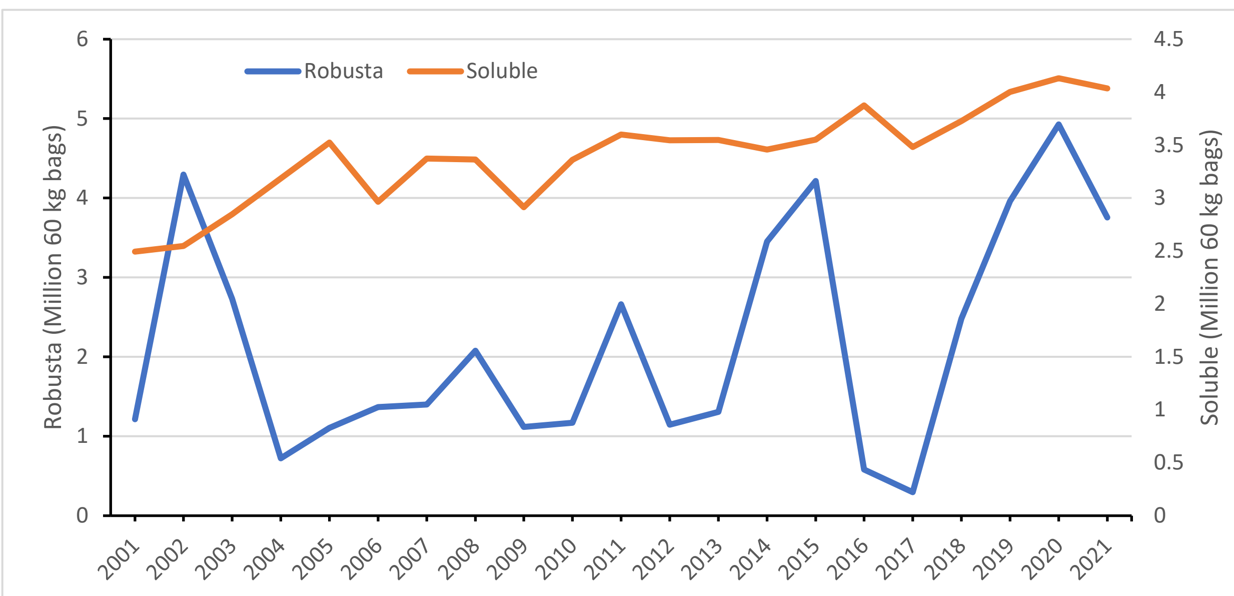
Figure 1. Domestic Coffee Consumption in Brazil



Brazil started exporting coffee beans in 1779 and coffee became Brazil's primary source of income and export earnings between 1800 and 1929. The 1929 stock market crash ended the golden age of coffee. More than 71,000 bags of coffee were burned by the Brazilian federal government, three years' worth of world consumption at the time. Brazil slowly restarted exports. In 1999, the Coffee Exporters Council (Cecafe) was formed to promote coffee exports and Brazil exported 23 million bags of coffee that year. Brazil is now the world's leading coffee exporter. (Cecafe, 2022) A record of 44 million bags were exported in 2020, surpassing the previous record of 41 million bags set in 2019. Moreover, 80 percent of the total exports in 2020 were Arabica coffee, with the remaining 20 percent consisting of Robusta beans and Robusta-based soluble coffee.

Figure 2 reflects the trend in Robusta beans and soluble-coffee exports over the years in Brazil. Robusta beans export demand is stable and predictable. In Brazil, one of the major determinants of the Robusta bean coffee exports supply is drought. It was a contributor to the low

Figure 2. Robusta and Soluble Coffee Exports of Brazil

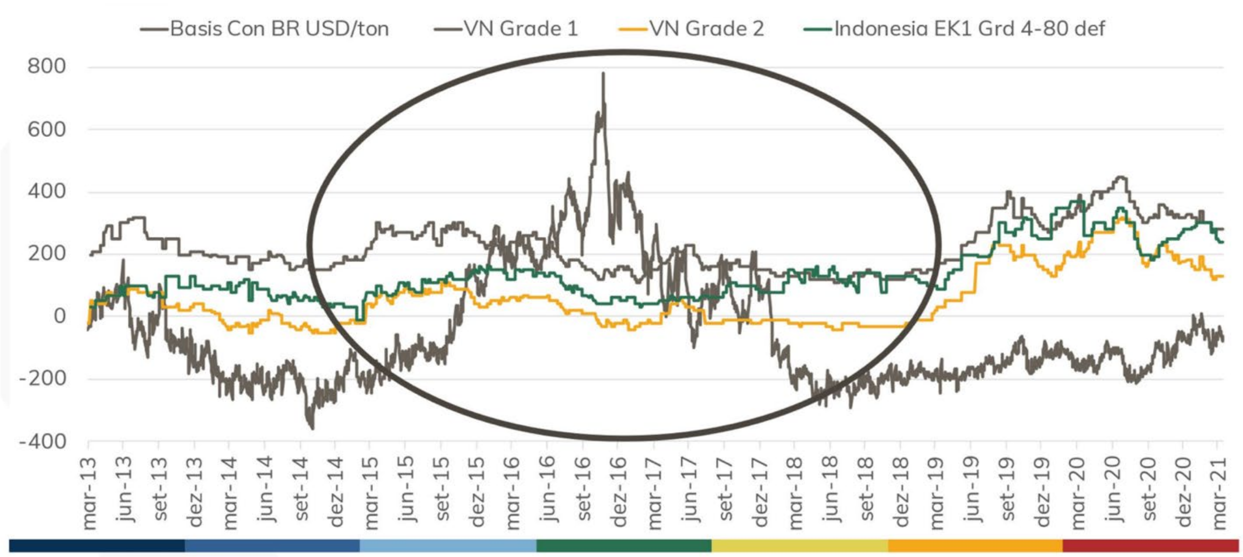


Robusta bean export, which nearly vanished between 2016 and 2017. Following the 2016-17 drought, they began recovering, and exports returned to their prior levels.

On the other hand, even though export of soluble coffee followed the same upward trend as Robusta coffee, it was less responsive to the drought. Additionally, when permitted, soluble coffee processors occasionally import green beans to make up for low domestic supply of Robusta green beans.

Coffee prices fluctuate due to the inelastic supply of coffee beans. This fluctuation was exacerbated by the trade ban imposed during the 2016-17 period which amplifies domestic scarcity. Figure 3 depicts the Robusta coffee basis in Brazil (Brazil local price-reference Robusta world price). The Brazilian basis which is usually negative (because of the excess supply) shot up in positive territory starting in late 2015 and peaking around fall 2016 but remained elevated and positive for most of 2017. Allowing Robusta imports into Brazil would have reduced basis considerably during that period.

Figure 3. Robusta Coffee Price Basis in Brazil

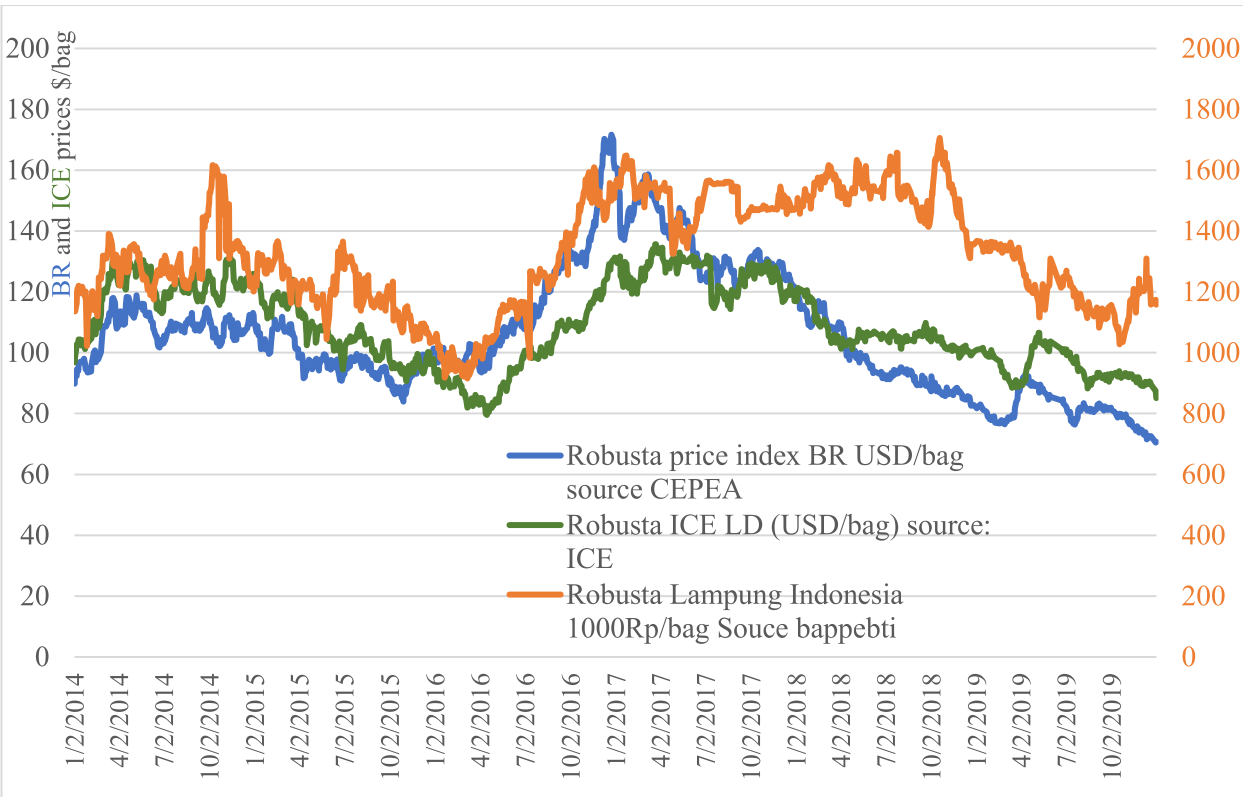


Source: Stonex

Figure 4 shows the correlated international prices for Robusta during 2014-2019. The series are the Brazilian Robusta price in $/bag, the ICE Robusta (all origins) futures price converted to

$/bag, and the Indonesia Robusta price in 1000Rp/bag. The impact of the Brazilian drought on world markets is telling despite the import ban. The progressive resumption of lower prices in 2018 is visible for the ICE and Brazilian prices. The Indonesian price remained elevated for longer and eventually converged back towards the other prices. In any case the shock in Brazilian prices in 2016-17 triggered price increases for the main Robusta markets.

Figure 4. Robusta International Prices



3. Modeling Approach

We build a multi-market partial-equilibrium model well-grounded in micro-economic foundations. The model captures key features of coffee-bean and soluble-coffee markets, differentiates consumer demand for green beans and soluble, and accounts for the intermediate demand for beans in soluble coffee processing which links the soluble and bean markets. We specify supply, demand,

and market clearing conditions for green beans and soluble markets in Brazil accounting for trade with the RoW. We link the Brazilian market to export and foreign markets for the two goods specifying excess demand or supply for the RoW. Market equilibrium provides closure by equating excess supply or demand domestically with its counterpart in the RoW. Our model allows us to solve for endogenous equilibrium prices for Robusta bean and soluble coffee, which are affected by the initial shock in supply from the drought and then the temporarily imposed ban on imports.

Next, we describe the structure of the equations for the demand and supply elements of the model and market equilibrium conditions. In the following equations, parameters B represent variables not affected by the shocks in the model hence subsumed in these aggregate terms. These B parameters are used to calibrate the model on observed data during the drought and trade ban regime in 2016-17. These elements are then held constant in the simulations.

The soluble market

The domestic consumer demand for soluble coffee, Q_{sol_d}, is represented by:

$Q_{sol_d} = B_{sol_d} P_{sol_d}^{\eta_{sol_d}}$, (1)

where B_{sol_d} subsumes all other determinants of domestic demand that are assumed to remain constant, P_{sol_d} is domestic price of soluble coffee, and ηsol_d is the domestic own-price elasticity of demand for soluble coffee.

Export demand from foreign consumers, Q_{sol_e}, is:

$Q_{sol_e} = B_{sol_e} P_{sol_e}^{\eta_{sol_e}}$, (2)

where B_{sol_e} incorporates all other determinants of export demand that are assumed to remain constant, P_{sol_d} is world price of soluble coffee, and ηsol_e is export own-price elasticity of demand for soluble coffee.

Under the assumption of constant return to scale (CRS) in soluble coffee production, cost exhausts revenue and output price is expressed as equal to two cost components: the price of green beans multiplied by an optimized bean requirement per unit of soluble coffee explained in equation (7) below, and a second element B_{sol_p} representing the minimized cost of other inputs per unit of output. The domestic soluble price, P_{sol_d}, is then:

$P_{sol_d} = \left(Q_{gn_{dd}}/Q_{sol}\right)P_{gn_d} + B_{sol_p}$. (3)

Market clearing condition for soluble coffee is realized at the intersection of total demand and the horizontal unit cost curve representing the soluble supply, Q_{sol}, under CRS:

$Q_{sol} = Q_{sol_d} + Q_{sol_e}$. (4)

We assume that the domestic price of soluble P_{sol_d} is equal to the export soluble price P_{sol_e} as a simplifying assumption, which is innocuous. A margin could be added which would not alter the results. The equality of the two prices is:

$P_{sol_e} = P_{sol_d}$. (5)

The green Robusta market

Final consumer demand for green beans, $Q_{gn_{fd}}$, is:

$Q_{gn_{fd}} = B_{gn_{fd}} P_{gn_d}^{\eta_{gn_{fd}}}$, (6)

where $B_{gn_{fd}}$ represents all other determinants of final consumer demand for green beans that are assumed to remain constant and $\eta_{gn_{fd}}$ is the domestic own-price elasticity of final demand for green beans.

Derived demand for green beans, $Q_{gn_{dd}}$, is:

$Q_{gn_{dd}} = P_{gn_d}^{-\alpha_{gn_d}\sigma_{gn_d}} Q_{sol} B_{gn_{dd}}$, (7) where $B_{gn_{dd}}$ subsumes all other determinants of derived demand for green beans that are assumed to remain constant, α_{gn_d} is the green-bean share of soluble coffee cost, and σ_{gn_d} is the elasticity of substitution for domestic green beans assumed very low to capture the near proportion between beans and soluble coffee.

Total domestic demand for green beans, Q_{gn_d}, is:

$Q_{gn_d} = Q_{gn_{dd}} + Q_{gn_{fd}}$. (8)

Export Demand and import supply for green beans from the RoW (foreign consumers and soluble processors for demand and bean suppliers for imports), Q_{gn_e}, has 3 regimes because of the trade reversal under the drought. It is characterized as follows:

$Q_{gn_e} = a - bP_{gn_e}$, (9)

where Q_{gn_e} $\begin{cases} is\ excess\ supply\ of\ the\ RoW\ if\ Q_{gn_e} < 0 \text{ (Scenario 1)} \\ is\ excess\ demand\ of\ the\ RoW\ if\ Q_{gn_e} > 0 \quad (Scenario\ 2) \\ and\ Q_{gn_e} = 0\ \ represents\ import\ ban\ , \end{cases}$

and parameters *a* and *b* are intercept and slope of the linearized excess supply and excess demand of the ROW. Their values are obtained by the point-slope formula with the given world excess supply elasticity set equal to 5 and 10, and to solve for the endogenous world price of green beans, P_{gn_e}, for Scenario 1 and Scenario 2 and we have related P_{gn_e} to P_{gn_d} such that P_{gn_e} has 12 percent markup over P_{gn_d} based on the average markup historically.

Bean supply is:

$Q_{gn} = P_{gn_d}^{\epsilon}(1 - K)B_{gn}$, (10)

where *K* is the supply shock from the drought to be imposed in calibration and then removed in the 2d scenario simulation, and B_{gn} is all other determinants of green bean supply that are assumed to remain constant, and ϵ is output response elasticity of green beans.

The market clearing condition for green beans equates supply and total demand for beans:

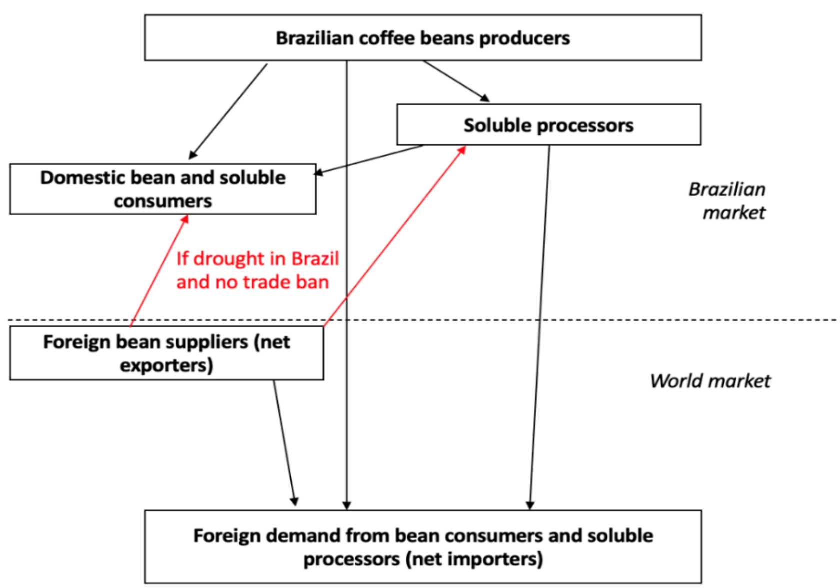
$Q_{gn} = Q_{gn_d} + Q_{gn_e}$. (11)

Trade reversal

Brazil is a large exporter of Robusta beans in normal production conditions. We model the trade reversal that would take place with a large drought as follows. Under the drought (parameter K equal to 31.07%) and with the import ban in place, import supply is quantitatively restricted to zero and the domestic price rises above the international bean price to establish domestic equilibrium under that import constraint and the drought. Then, we measure the trade and welfare implication of the trade ban by removing it and allowing world price and domestic price of beans to be linked by market forces. The domestic price of beans falls until there is arbitrage between the two markets. Foreign excess supply expands into the Brazilian bean market because of the initial price differential created by the ban before its removal. This way, we can gauge how much coffee Brazil would have imported under the drought and without banning imports.

Figure 5 shows the Brazilian and World markets with their simplified supply chain.

Figure 5. Robusta Coffee Supply Chain and Trade Flows



Black arrows indicate the regular trade pattern from source to destination in absence of drought. Red arrows should the change in trade with the drought and without the ban. The ban changes the domestic Brazilian market into a nontraded market with the now endogenous domestic price clearing the constrained market.

Welfare Analysis

Next, we proceed with welfare measurement using usual surplus measures. Change in the final-consumer surplus resulting from the domestic consumption (subscript *d*) of Brazilian green bean and soluble coffee (*i*=*gn*, *sol*), for scenarios 1 and 2 (*k*=1, 2) is denoted as ΔCS_{idk}. It is:

$\Delta CS_{id1} = B_{id}\left(\int_{P_{id1}}^{P_{idc}} P_{id}^{\eta_{id}}\, dP\right)$, and $\Delta CS_{id2} = B_{id}\left(\int_{P_{id2}}^{P_{id1}} P_{id}^{\eta_{id}}\, dP\right)$, (12) $with$ *i*=Brazilian green bean or soluble coffee, and where P_{idk} is the price of the corresponding type of Brazilian coffee either in the domestic market for either scenario k. Variables B_{ij} and η_{ij} refer to the same variables in equations (1) and (6), the intercept parameter and elasticity specific for each coffee product.

Since Brazilian soluble coffee production is assumed to exhibit CRS, there is not surplus strictly speaking as revenues and cost are equalized. To capture the impact of the scenarios in soluble coffee production, we consider cost savings of the soluble coffee processing industry. In Scenario 1, it is $CSAVE_1$, and is measured as:

$$CSAVE_1 = Q_{gn_{ddc}} \times \left(P_{gn_{dc}} - P_{gn_{d1}}\right) + \frac{\left(Q_{gn_{dd1}} - Q_{gn_{ddc}}\right) \times \left(P_{gn_{dc}} - P_{gn_{d1}}\right)}{2}, \quad (13)$$

where, $Q_{gn_{ddc}}$ and $P_{gn_{dc}}$ are derived demand and price of green beans at calibration point, $Q_{gn_{dd1}}$ and $P_{gn_{d1}}$ are derived demand and price of green beans in Scenario 1.

Cost savings of the soluble coffee processing industry in Scenario 2, $CSAVE_2$, is similarly derived as:

$$CSAVE_2 = Q_{gn_{dd1}} \times \left(P_{gn_{d1}} - P_{gn_{d2}}\right) + \frac{\left(Q_{gn_{dd2}} - Q_{gn_{dd1}}\right) \times \left(P_{gn_{d1}} - P_{gn_{d2}}\right)}{2}, (14)$$

where, $Q_{gn_{dd2}}$ and $P_{gn_{d2}}$ are derived demand and price of green beans in Scenario 2.

Green-bean producer surplus change in Brazil from removing the import ban, ΔPS_{d1}, is measured as:

$$\Delta PS_{d1} = -(1-K)B_{gn} \int_{P_{gn_{d1}}}^{P_{gn_{dc}}} P_{gn_d}^{\in} dP, (15)$$

where, $P_{gn_{d1}}$ is domestic price of green beans in Scenario 1.

The Robusta producer surplus change in Brazil from removing the drought, ΔPS_{d2}, involves a shift of the supply curve. It is expressed as the difference between the two producer surpluses, one without the drought and one with. It is measured as:

$$\Delta PS_{d2} = (1-K_2)B_{gn} \int_0^{P_{gn_{d2}}} P_{gn_d}^{\epsilon}\ dP - \ (1-K_1)B_{gn} \int_0^{P_{gn_{d1}}} P_{gn_d}^{\epsilon}\ dP, (16)$$

where $P_{gn_{d2}}$ is domestic price of green beans in Brazil in Scenario 2, K_1 is 0.3107 implying the drought and K_2 is zero implying no drought.

The surplus increase in the RoW for net bean exporters in Scenario 1, ΔSE_{RoW1}, is measured as:

$$\Delta SE_{RoW1} = \frac{(P_{gn_{e1}} - P_{gn_{ec}}) \times (Q_{gn_{eROW1}} - Q_{gn_{eROWc}})}{2} + \ Q_{gn_{eROWc}}\ \times (P_{gn_{e1}} - P_{gn_{ec}}), (17)$$

where $P_{gn_{e1}}$ and $P_{gn_{ec}}$ are the price of green beans in the world market in Scenario 1 and at the calibration point; $Q_{gn_{eROW1}}$ is the excess supply of the RoW in Scenario 1, and, $Q_{gn_{eRoWc}}$ refers to green beans that are sourced and traded in the RoW at calibration time.[1] In (17), the first component accounts for the gains from RoW's exports to Brazil when the ban is removed and the second component accounts for the price suppression effect of the ban on net exporters on their total

[1] $Q_{gn_{eRoWc}}$ is obtained from ICO as total exports of the largest Robusta producers, Vietnam, Uganda, Indonesia, India, Laos, and Ivory Costs, and is summing up to 45 million 60-kg bags (rounded) for the calibrated period.

exports outside of Brazil under the ban (a rectangle of rents). This second component also reflects the transfer between net importers and net exporters, outside of Brazil from the price suppression effect of the ban The ban mutes the impact of the drought and reduces prices below $P_{gn_{e1}}$.

The latter price is the source of the most substantial transfer reflecting the impact Brazilian drought has on other countries trading coffee because it has market power in world markets. This effect is measured formally in Scenario 2. The surplus loss of net bean exporters in the RoW in Scenario 2, ΔSE_{RoW2}, follows a similar logic. It is measured as:

$$\Delta SE_{RoW2} = \frac{(P_{gn_{e2}} - P_{gn_{e1}}) \times (Q_{gn_{eROW2}} - Q_{gn_{eROW1}})}{2} + Q_{gn_{eROW2}} \times (P_{gn_{e2}} - P_{gn_{e1}}), \quad (18)$$

where, $P_{gn_{e2}}$ is the price of green beans in the world market under the removal of the drought. Therefore, ΔSE_{RoW2} captures the loss to net exporters from lower prices on all units sold under no drought, and the adjustment of net exports from RoW when prices fall (a move along the net export supply).

For net importers in RoW, related welfare magnitudes reflect the transfers to net exporters and their changes, using the similar prices as in (17) and (18), but accounting for imports by Brazil in Scenario 1 ($Q_{gn_{e1}} < 0$), and exports by Brazil in Scenario 2 ($Q_{gn_{e2}} > 0$). These changes in surplus ΔSI_{RoWi} (scenario *i*=1,2) are:

$$\Delta SI_{RoW1} = \frac{(P_{gn_{e1}} - P_{gn_{ec}}) \times Q_{gn_{e1}}}{2} - Q_{gn_{eROWc}} \times (P_{gn_{e1}} - P_{gn_{ec}}), \quad (19) \text{ and,}$$

$$\Delta SI_{RoW2} = \frac{(P_{gn_{e1}} - P_{gn_{e2}}) \times (Q_{gn_{e2}} - Q_{gn_{e1}})}{2} + (Q_{gn_{eROWc}} + Q_{gn_{e1}}) \times (P_{gn_{e1}} - P_{gn_{e2}}) \quad (20).$$

Finally, foreign buyers of Brazilian soluble coffee also experience welfare changes $\Delta CS_{sol_{e}k}$ under both scenarios (*k*=1, 2):

$$\Delta CS_{sol_{e}1} = B_{sol_e}\left(\int_{P_{sol_{e1}}}^{P_{sol_{ec}}} P_{sol_{e}e}^{-\eta_{sol_e}}\, dP\right), \text{ and } \Delta CS_{sol_{e}2} = B_{sol_e}\left(\int_{P_{sol_{e2}}}^{P_{sol_{e1}}} P_{sol_e}^{-\eta_{sol_e}}\, dP\right) \quad (21)$$

We abstract from the impact on the world equilibrium in soluble coffee in our analysis, or equivalently, we treat the export demand for Brazilian soluble coffee as a differentiated-product demand reaching equilibrium expressed in (4).

Deadweight losses

We approximate deadweight losses induced by the ban using linearization and compute triangles in production and consumption using differences in prices and quantities. The deadweight loss in Brazil bean production from the protective effect of the import ban, $DWL_{production}$, is measured as:

$DWL_{production} = \frac{(Q_{gnc} - Q_{gn1}) \times (P_{gn_{dc}} - P_{gn_{d1}})}{2}$, (22)

where, Q_{gnc} and Q_{gn1} are green bean output in Brazil at calibration point, and in Scenario 1. Their variation is small given the lack of price response in Brazilian bean production.

Similarly, the deadweight loss from the bean consumption distortion due to the import ban, $DWL_{consumption}$, is measured as:

$DWL_{consumption} = \frac{\left(Q_{gn_{d1}} - Q_{gn_{dc}}\right) \times \left(P_{gn_{dc}} - P_{gn_{d1}}\right)}{2}$, (23)

where, $Q_{gn_{dc}}$ and $Q_{gn_{d1}}$ are domestic demand of green beans at calibration point and in Scenario 1.

Finally, deadweight loss in soluble coffee demand due to import ban, $DWL_{soluble}$, is measured as:

$DWL_{soluble} = \frac{(P_{solc} - P_{sol1}) \times (Q_{sol1} - Q_{solc})}{2}$, (24)

where, P_{solc} and P_{sol1} are the prices of soluble, and Q_{solc} and Q_{sol1} are the soluble quantities demanded at calibration point and in Scenario 1.

4. Calibration and Timing of Scenarios

We calibrate existing data from 2016/2017 marketing year which represents the state of the world where there is a drought and import ban. We source our data for green bean production and soluble consumption from USDA Foreign Agricultural Service, domestic and world price of green beans from CEPEA and ICO respectively, and export volume of green beans and soluble coffee from CECAFE. Price and quantity variables and cost share parameter are defined in Table 1 and elasticity parameters and values are shown in Table 2.

Table 1. Variables Used in the Model

Abbreviation	Description	Sources	Value at calibration
P_{gn_d}	Domestic price of green bean	CEPEA	138.45
P_{gn_e}	World price of green bean	ICO	124.25
P_{sol}	Domestic and world price of soluble coffee	CECAFE	177.68
α_{gn_d}	Cost share of green beans in soluble coffee		0.77
$Q_{gn_{dd}}$	Derived demand of green bean		4.84
$Q_{gn_{fd}}$	Final demand of green bean		5.39
Q_{gn_d}	Domestic demand of green bean		10.23
Q_{gn_e}	Exports(imports) green bean	CECAFE	0
Q_{gn}	Green bean production	USDA	10.5
Q_{sol_d}	Domestic demand of soluble coffee	USDA	1.09
Q_{sol_e}	Export demand of soluble coffee	CECAFE	3.75
Q_{sol}	Soluble coffee production		4.84

In the parametrization, we assume an extremely low substitution elasticity for Robusta coffee beans in soluble coffee production to express its nearly fixed proportion between beans and soluble coffee. The CRS assumption in domestic soluble coffee production, leads to equal price and unit cost for soluble coffee. Finally, we assume a nearly vertical green coffee supply for Robusta production in Brazil. The elasticity of export demand faced by Brazil and from the RoW is calibrated first on historical data at exports of 2.92 million bags and price equal to $111.54/bag which are average values for 2013-15 assumed to be free of drought effect. The export demand is linear as shown in (9). Once Brazil becomes a net importer, this export demand becomes a supply of imports for Brazil (Brazilian exports become negative). Hence given the linear function (9), the elasticity varies along that excess demand/supply curve, it decreases in absolute value as the trade flow gets closer to zero. It is exactly zero at the ban and starts increasing as imports get in Brazil in Scenario 1.

Table 2. Elasticities and Values

Symbol	Description	Value
ηsol_d	Domestic price elasticity of demand for soluble coffee	-0.1
ηsol_e	Export price elasticity of demand for soluble coffee	-1.1
σ_{gn_d}	Own elasticity of substitution for domestic green beans	0.012*
$\eta_{gn_{dd}}$	Domestic price elasticity of derived demand for green Robusta beans	-0.01
$\eta_{gn_{fd}}$	Domestic price elasticity of final demand for green Robusta beans	-0.1
$\lvert\eta_{gn_e}\rvert$	Absolute value of RoW import demand/export supply price elasticity for green Robusta beans	5 and 10
ε	Domestic green Robusta bean output response elasticity	0.01

*Value under drought and ban

The simulations are presented in a reverse chronological order compared to the actual events. We start from the baseline state of the world characterized by drought conditions and the import ban in Brazil. In the first scenario we remove the import ban to measure its impact. Subsequently, in the second scenario we eliminate the drought to measure the impact of the latter and assuming no ban.

5. Simulation Results

In the calibration run, the exogenous shock in Robusta production reduces the domestic supply of Robusta beans by around 31.07 percent as observed in the data. It induces an increase in world prices, as global supplies are reduced. A trade-pattern reversal from exports to imports of Robusta beans would ensue in the absence of the trade ban. The ban prevents imports to come in Brazil. The domestic price of beans increases to clear the domestic market. The higher bean price feeds back into soluble production and soluble quantities consumed domestically and overseas are repressed by the ban. Export from the RoW into Brazil are prevented and the increase in the world price of beans is limited by the ban.

As shown in Table 3, in Scenario 1 with the ban removal, expected effects take place. The local price of coffee products falls, all domestic consumptions increase; the world price of coffee increases as Brazil imports Robusta beans and exports of Brazilian soluble coffee also increase. The quantity of green beans imported into Brazil ranges from 325 to 690 thousand 60-kg bags, assuming a world supply elasticity of 5 and 10.

Table 3. Scenario Results with Prices (in USD/60kg bag) and Quantities (in million 60 kg bags) at Calibration and Under Scenarios

Variable	Calibration Drought & Ban	Scenario 1 w/ η_{gn_e}=5	Scenario 1 w/ η_{gn_e}=10	Scenario 2 w/ η_{gn_e}=5	Scenario 2 w/η_{gn_e}=10
Local price green bean	138.45	121.7	111.87	96.19	97.64
World price green bean	124.25	136.3	125.3	107.73	109.36
Price soluble coffee	177.68	161.18	151.54	136.1	137.53
Cost share of beans in soluble	0.77	0.75	0.74	0.71	0.71
Derived demand green bean	4.84	5.28	5.59	6.19	6.12
Final demand green bean	5.39	5.45	5.5	5.58	5.58
Total demand green bean	10.23	10.745	11.1	11.78	11.71
Exports (imports) green bean	0	-0.325	-0.69	3.44	3.51
Green bean production in Brazil	10.5	10.42	10.41	15.22	15.22
Local demand soluble	1.09	1.1	1.1	1.11	1.11
Export demand soluble	3.75	4.17	4.46	5.02	4.97
Production soluble	4.84	5.27	5.57	6.14	6.08

**Scenario 1 is removal of trade ban and Scenario 2 is removal of drought under no trade ban.*

Welfare effects of Scenario 1 are shown in Table 4. With the removal of the ban and relative to the calibrated equilibrium, the simulations indicate that the import ban was helping Brazilian bean producers but hurting soluble processors and final consumers in Brazil, while major Robusta exporters, such as Vietnam, suffered from the ban via lower prices. Foreign consumers of Brazilian soluble coffee faced higher prices and experience welfare losses. The removal of the

Table 4. Welfare Effects of Scenario 1 (Removing the Import Ban) and Scenario 2 (Drought Disappearance)

Scenarios		Soluble coffee markets				Green bean markets	
Ban removal		$\lvert\eta_{gn_e}\rvert = 5$	$\lvert\eta_{gn_e}\rvert = 10$			$\lvert\eta_{gn_e}\rvert = 5$	$\lvert\eta_{gn_e}\rvert = 10$
Consumer Surplus change from removing the ban	Brazilian consumers	18.07	28.71	Consumer Surplus from removal of the ban	Domestic	90.85	144.74
	foreign buyers	65.25	106.88		RoW net importers	-540.29	-46.89
Processing cost change from removing the ban	Brazilian processors cost change	-84.75	-138.6	Producer Surplus change from removal the ban	Domestic	-174.66	-277
	RoW	N/A	N/A		RoW net exporters	544.21	47.61
Drought removal							
Consumer Surplus change from removing the drought	Brazilian consumers	28.83	15.58	Consumer Surplus change from removing the drought	Brazilian consumers	140.87	78.87
	foreign buyers	114.76	65.99		net importers in RoW	1,330.15	739.78
Processing cost change from removing the drought	Brazilian processors cost change	-146.29	-83.31	Producer Surplus change from removing the drought	Brazilian producers	194	318.47
	RoW	N/A	N/A		Net exporters in RoW	-1,241.15	-694.82

ban reversed all these tendencies as shown in the table. Brazilian bean producers lose between \$175 million to \$277 million depending on the assumed elasticity for the excess supply from the RoW. Most of the change in producer surplus is from consumers regaining former producer rents created by the ban. Without the ban, final consumers in Brazil and foreign buyers of soluble coffee regain between \$174 million and \$280 million.

Interestingly, transfers in the RoW's bean market are larger (\$540 million under $|\boldsymbol{\eta}_{gn_e}| = \mathbf{5}$), which comes from the large volume traded (around 45 million bags) and the large price change (from \$124.25 to \$136.3). Once the ban is removed, net bean importers in RoW pay more and transfer these additional payments to net exporters. The latter result shows that trade restrictions imposed by natural exporters can have elaborate consequences when price setting power exists. Under the assumption of a more price elastic excess supply/demand curve ($|\boldsymbol{\eta}_{gn_e}| = \mathbf{10}$), the Robusta world price changes by a mere dollar, and the transfer is small (\$47 million).

Deadweight losses from the ban were small to nearly negligible because Robusta bean supply is almost vertical and demand for beans is not price elastic. Deadweight losses in the Brazilian bean market fall by \$0.67 million in production, and by \$0.50 million in consumption with the ban removal. These are a bit larger when the world market is assumed more price-elastic, but still amount to \$2.66 million, rather than \$1.17 million under less price response in world markets. Some moderate deadweight loss reductions take place in the domestic soluble market as the unit cost falls with cheaper beans (\$0.08 to \$0.26 million). Deadweight losses induced by the ban were much larger in the export soluble market. The removal of the ban induces reductions in soluble distortions of \$3.46 million to \$9.28 million depending on the assumed price responsiveness in the world bean market. In conclusion the ban had transferred rents to bean producers from buyers but at a small efficiency cost.

Next, we turn to the impact of the drought itself. These are shown in Table 3 in terms of prices and quantities, and their welfare effects are shown in Table 4. The production shock had reduced supply by 31.07%. in absence of drought supply reaches 15.22 million bags, prices fall for all markets and products, and trade of Brazilian products expand with bean exports reaching 3.44 to 3.51 million bags depending on the price responsiveness of world markets. Welfare effects are large given the shift in bean supply. No drought translates in producer surplus increases of \$194 million to \$318 million despite price falling. Brazilian bean consumers gain between \$141 million to \$79 million. Domestic soluble consumers gain \$29 million to \$16 million and foreign soluble buyers gain between \$115 million to \$66 million. These range depend on the assumed price responsiveness of world bean markets.

The welfare impact of the drought or its vanishing on world bean markets are arresting: net importers regain between \$1,330 million to \$740 million with the drought gone while net exporters see their surplus shrink by between \$1,241 million and \$695 million, depending on the assumed responsiveness of the world bean market.

It is also interesting to note the comparable magnitude in the Brazilian producer surplus changes in the two scenarios. The drought initially induced significant losses to Brazilian producers, which were almost offset by the trade ban, at the cost of bean and soluble buyers, and induced small inefficiency losses.

6. Conclusions

The findings of the investigation suggest that the exogenous supply shock in Brazilian Robusta coffee considerably disrupted the dynamics of the world Robusta coffee market, impacting a range of market participants. The trade ban motivated to protect Brazilian farmers from the drought had substantial welfare implications generating significant transfers between buyers and sellers of coffee, but small deadweight losses in Brazilian markets. The ban mitigated the large transfer from net importers to net exporters in the RoW initially created by the supply shock. Hence, an unintended consequence of the ban is that it provided some benefits to net bean importers in the RoW. However, the ban increased the price of soluble coffee and resulted in losses to foreign buyers of Brazilian soluble coffee. The relative magnitudes of these effects hinges on the price responsiveness of the RoW excess supply/demand. Stronger price and welfare effects are estimated when these elasticities are smaller in absolute value.

The welfare losses of consumers of coffee beans and soluble coffee from the trade ban were comparable to the initial welfare loss induced by the original drought shock, hence a bitter double whammy for these consumers, with the ban piling up losses induced by the drought.

The trade ban effectively mitigates the loss to producers induced by the original drought shock. In addition, the ban is an effective way to transfer surplus from consumers and users to coffee farmers with small deadweight losses induced. The ban impacted foreign market participants (higher price of soluble and lower trade opportunities for net-exporting foreign suppliers like Vietnam).

Future research could focus on targeted policy alternatives to the trade ban such as drought income assistance or yield insurance. The latter policies would require some fiscal resources but would reduce the aggregate cost of gross market interventions such a trade ban. They may elucidate less disruptive means of protecting domestic producers during shocks. A more extensive use of hedging could also help market participants to hedge price risk induced by volatile prices induced by natural shocks.

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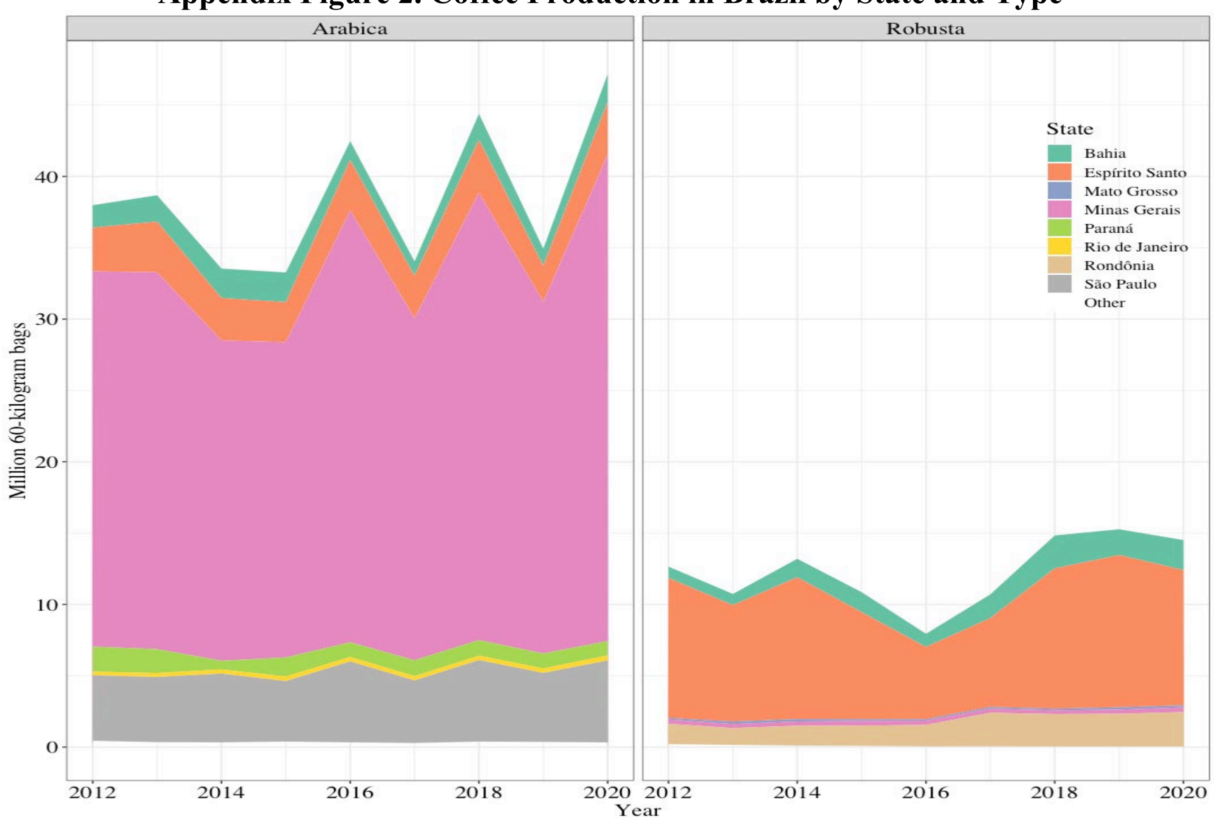
Appendix

Appendix Figure 1. Contrasting Arabica vs. Robusta Coffee

Appendix Figure 2. Coffee Production in Brazil by State and Type



Source: Municipal Agricultural Survey