ESSAYS ON BRAZILIAN AGRICULTURAL PRODUCTION AND POLICY

A Dissertation

by

YURI CLEMENTS DAGLIA CALIL

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Chair of Committee,	Luis Ribera
Co-Chair of Committee,	Henry Bryant
Committee Members,	David Anderson
	Hwagyun Kim
Head of Department,	Mark Waller

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ABSTRACT

We show how physical, morphological, genetic, and market factors affect the price of purebred Nellore sold at auctions in Brazil. We perform a hedonic analysis under a hierarchical model to document that visual scores and Expected Progenies Differences (EPDs) explain variations in prices. A morphological index bears higher premiums than a genetic index, while auction type and reputation explain variations in prices. We quantify the possible effects of a European Union–Mercosur Free Trade Agreement on agricultural markets. We develop a gravity model of international trade in a general equilibrium framework to investigate the effects of the Free Trade Agreement (FTA) on selected agricultural products: chicken, cattle, pig, cotton, soybean, wheat, and maize. The results show Mercosur countries (Argentina, Brazil, Paraguay, and Uruguay) increasing their agricultural exports, especially to Europe, but with relatively small welfare gains. The European countries may reduce their exports to their fellow countries, but with more considerable welfare gains, especially in the meat sector. We investigate the economic feasibility of the Brazilian crop-livestock integration system. Under this system, the Brazilian farmer can produce soybean, corn, and cattle in the same land during one crop-year. We contrasted the stochastic net present value of traditional farming with the integrated system under four different scenarios. The results suggest more significant economic gains for crop-livestock integration scenarios.

DEDICATION

I dedicate all my efforts to my kids: Jorge Victor Orsini Calil and Elena Orsini Calil. “Lead by example.” I expect to inspire my children to follow the aggies spirit and values: excellence, integrity, leadership, loyalty, respect, and selfless service.

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1. INTRODUCTION

We investigated Brazilian agricultural production and policy on three fronts. First, we examine the price formation of animals sold at auctions. Second, we observe the variations in price, volume, and welfare, given the free trade agreement that Brazil recently signed. Finally, we evaluate the economic viability of a new production technique that has been spreading rapidly across Brazil.

Brazil is a leading producer and exporter of beef. Nellore, a Bos indicus breed, is the cornerstone of the country's livestock production. Neither purebred Bos indicus breeds nor the Brazilian livestock economy has been examined in the literature to date. We perform a hedonic analysis under a hierarchical model to investigate how physical, morphological, genetic, and market factors affect the price of purebred Nellore sold at auctions in Brazil.

Southern Common Market (Mercosur) and the European Union (EU) signed a free-trade agreement (FTA) in 2019. EU–Mercosur FTA may affect international agricultural trade prices and volumes. We investigate the possible effects of an EU–Mercosur FTA on agricultural markets. We develop a gravity model of international trade in a general equilibrium framework to evaluate the effects of the FTA on selected agricultural products: chicken, cattle, hog, cotton, soybean, wheat, and maize.

Crop-Livestock Integration System allows a farmer to rotate three different cultures during the same crop season, for instance: soybean, corn, and cattle. Such a technique, besides increase productivity, has sustainable appeal. We evaluate the economic feasibility of the Crop-Livestock Integration System, contrasting with the traditional soybean and corn production in Brazil. In order to do that, we developed a stochastic net present value (NPV) model using a unique database from Brazil.

2. PUREBRED NELLORE PRICES IN BRAZIL: MORPHOLOGICAL, GENETIC, PHYSICAL, AND MARKET FACTORS IN AUCTIONS

2.1. Introduction

Brazil is a crucial player in the world beef market. In 2017, it was the world's second-leading producer and exporter and the third-largest consumer (USDA, 2018). In 2016, the meat supply chain accounted for 6% of Brazilian GDP and 30% of agribusiness GDP (CEPEA, 2017). Brazil's competitiveness is rooted in the success of the Nellore breed, which accounts for over 80% of Brazilian beef cattle, and the country's extensive grasslands (Rosa & Menezes, 2016). Although the country is relevant in the international beef market, there is a surprising paucity of studies examining livestock prices.

Hedonic models have long been used to examine how characteristics affect cattle prices. The literature evaluates physical, market, regional, temporal factors in U.S. livestock auctions. The majority of the studies address feeder cattle (Buccola (1980); Faminow and Gum (1986); Schroeder et al. (1988); Bailey et al. (1991); Williams et al. (2012); Zimmerman et al. (2012); Schulz et al. (2015); Mallory et al. (2016); Blank et al. (2016)), but researches have also scrutinized cow-calf pairs Parcell et al. (1995), cull cows Mintert et al. (1990), bred heifers (Parcell et al., 2010), bred cows Mitchell et al. (2018), and pure-bred bulls.

Relatively few projects have studied purebred bull prices. Dhuyvetter et al. (1996) investigate the physical, market, and genetic characteristics in seven breeds in

Kansas auctions using a hedonic model. Chvosta et al. (2001) examine market, performance, and genetic attributes of Angus cattle in Nebraska, South Dakota, and Montana auctions using a hedonic model. Vanek et al. (2008) and Jones et al. (2008) evaluate the economic value of Angus seedstock traits, the former using data from four U.S. ranches and the latter using data from 11 U.S. states. Vestal et al. (2013) explore Angus performance and genetic features in Oklahoma auctions, combining revealed and stated preferences in a hedonic model. All of these studies analyze Bos taurus cattle, the most common breed in the United States.

Less research investigates Bos indicus breeds. Cattle breeds are divided into two main groups: B. taurus and B. indicus. B. taurus breeds (e.g., Angus, Charolais, Hereford) are suited to temperate climates and derived from European stocks. B. indicus breeds (e.g., Brahman, Nellore, and Guzerat) are tropical strains derived from Indian stocks and are characterized by a hump on their backs (Garrick & Ruvinsky, 2014). Although some research investigates the influence of Brahmans, an important B. indicus breed in southern U.S. beef production, no feeder cattle prices differentials to date (Williams et al. (2012); Zimmerman et al. (2012); Mallory et al. (2016)), have examined purebred animals.

This research uses a unique dataset from Brazilian cattle auctions with 25 attributes for each Nellore seedstock lot. Given the lack of knowledge about B. indicus price determinants and prompted by the studies mentioned above, our research addresses physical, morphological, genetic, and market factors that influence the price of Nellore purebred bulls sold at auctions in Brazil. Further, contrasting the implicit prices of U.S.

Angus and Brazilian Nellore attributes contributes insights about livestock production priorities in both markets.

Studying seedstock farms is relevant to the beef sector. Purebred farms drive genetic improvements through selective breeding and supplying bulls to the market, especially in auctions. Genetic improvements are an essential component of beef farm profitability since they influence yearling weight, carcass weight, cow weight, calving ease, heifer pregnancy, marbling, and other performance measures. As a result, a commercial farmer can anticipate better efficiency once the sire of his choice passes these desirable features to its offspring. Thus, seedstock distributes the desired results throughout the production system.

In the selective breeding process, Brazilian seedstock farmers have two indices at their disposal: EPMURAS and MGTe. The EPMURAS morphological index, constructed by BrasilcomZ, sums body structure, precocity, muscling, navel, conformation, soundness of feet and legs, and reproductive soundness scores (BrasilcomZ, 2018). The National Association of Breeders and Researchers (ANCP) developed the Economic Total Genetic Merit (MGTe) index, a weighted average of genetic attributes such as expected progeny differences (EPD) for precocity, maternal ability, pre- and post-weaning growth, fertility, stayability, and carcass (ANCP, 2018). Findings suggest higher premiums for the EPMURAS index than for the MGTe index.

We compare the weights of these indices constructed by animal scientists with the marginal value of weights derived from our hedonic model. The results point to the valuation of characteristics related to precocity and functional biotype. The marginal value of each attribute can play a fundamental role not only in establishing the characteristics that will be privileged during the selective breeding process but also in pricing the animals that will not be traded at auctions. Further, generating and maintaining a database to construct these indexes is costly. So, it is necessary to understand its usefulness.

We determine premiums and discounts for some market characteristics. Adding to work by Chvosta et al. (2001) and Jones et al. (2008), we investigate farm reputation (brand). Our database allows us to compare auctions broadcast live with bids collected both on the premises and by phone and auctions broadcast with videos of lots recorded with bids collected only by phone. Brazil has seven TV channels that broadcast livestock auctions almost daily. Auctions are costly for the purebred farm promoter. The results not only contribute to ranchers' decisions about how to market their animals but also extend the research that found no structural price differences between traditional and satellite video auctions (Bailey and Peterson (1991)).

The results provide relevant information for both buyers and sellers. Buyers can use attribute values as a benchmark to decide whether to buy a bull. Sellers can understand purchasers' preferences for traits and, consequently, strategically decide which ones to foster in their herds.

2.2. Data

Table 2-1 reports summary statistics for the cross-sectional data, which were collected in 16 auctions in four Brazilian locations from 2013 to 2017. The sample size consists of 2,094 head comprising 1,275 lots of purebred Nellore males of reproductive age. Auction customers were seedstock producers and commercial cattle producers. Sale catalogs, available to customers before and during the events, provide information for each lot. We recorded information about the sale price and physical, morphological, genetic, and market characteristics and deleted missing and misreported data. Inflation-adjusted lot prices were calculated using the Brazilian General Price Index (IGP-DI).

Table 2-1 Summary Statistics

Variables	Mean	StDev	Min	Max
Price (R$/lot)	9,997.2	4,097.4	3,571.6	39,446.1
Physical				
Age (months)	31.43	4.40	19.63	58.07
Weight (pounds/lot)	1,554.4	188.8	992.8	2,171.6
Scrotal Circumference (cm)	36.76	2.59	26.5	46
Morphological (EPMURAS scores)				
Body Structure - E	4.83	0.65	3	6
Precocity – P	5.57	0.64	3	6
Muscling – M	5.51	0.69	3	6
Navel – U	1.89	0.32	0	2
Conformation – R	3.20	0.60	2	4
Soundness of Feet and Legs – A	3.17	0.48	2	4
Reproductive Soundness - S	3.94	0.23	2	4
EPMURAS quality Index	30.07	2.45	20.33	34
Genetics (EPD in percentiles)				
Total Genetic Merit Index - MGT	11.77	11.56	0.1	100
Maternal body weight at 120 days of age - MP120	22.91	21.15	0.1	100
Body weight at 210 days of age - DP210	20.99	18.16	0.1	100
Body weight at 450 days of age - DP450	13.77	13.28	0.1	80
Scrotal Circumference at 365 days of age - DPE365	15.98	15.24	0.1	90
Scrotal Circumference at 450 days of age - DPE450	17.64	16.91	0.1	100
Stayability - DSTAY	18.05	18.46	0.1	100

Table 2-1 Continued

Variables	Mean	StDev	Min	Max
Probability of Precocious Calving - DP3	33.69	27.36	0.1	100
Market Factors				
Number of heads in a lot (head)	1.64	0.88	1	5
Number of the lot (proxy for order)	81.96	37.88	1	149
Farm reputation	5.41	1.77	1	7
Auction Type	1.79	0.41	1	2
Auction Place	2.35	1.41	1	4

The physical variables recorded were age (months), weight (lb), and scrotal circumference (cm). Market characteristics collected from the catalog include the number of head in each lot, lot number, auction type, farm name (brand), and auction place. There are two types of auction. One kind is broadcast live, with bids collect on the premises and by phone. Another kind is broadcast with recorded lot videos, with bids collected only by phone. We refer to the first as "virtual and physical" and the second as "virtual."

The morphological variables consisted of the score for body structure (E), precocity (P), muscling (M), navel (U), conformation (R), soundness of feet and legs (A), reproductive soundness (S), and EPMURAS morphological quality index. Morphological traits are visual scores evaluated by BrazilcomZ.

Koury Filho (2005) developed the EPMURAS morphological index. The National Association of Breeders and Research (ANCP) and Brazilian Zebu Breeders Association (ABCZ), two major Brazilian breeding programs, use EPMURAS methodology as a selection tool. Traits E, P, and M are ranked from 1 (inferior) to 6 (excellent); traits R, A, and S are classified from 1 (inferior) to 4 (excellent). Grades of 2, 3, or 4 are for functional navel and 1, 5, and 6 for the not-functional navel. The EPMURAS index is the sum of all scores (except for navel, which adds four points for a score of 2, 3, or 4; two points for 1 or 5; and 1 point for 6).

The National Association of Breeders and Research (ANCP) issues expected progeny differences (EPDs) and percentile ranking tables for various traits. The catalog expresses the genetic variables in percentile ranking, referred to as TOPs, showing each animal's range. For instance, if a lot has TOP 5% for a particular characteristic, it means that the lot is among the 5% best Nellore in the breeding program for this attribute.

The genetic variables, expressed in percentiles, are scrotal circumference at 365 days of age (DPE365), scrotal circumference at 450 days of age (DPE450), maternal weaning weight (MP120), body weight at 210 days of age (DP210), body weight at 450 days of age (DP450), stayability (DSTAY), precocious calving probability (D3P), and total economics genetic merit (MGTe).

The MGTe index summarizes genetic value. ANCP estimates weights based on the profitability impact of these genetic characteristics on full-scale commercial beef cattle operations (breeding, rearing, and fattening) located in Midwest Brazil (ANCP, 2018). MGTe weights are as follows: 6% DIPP, 9% D3P, 3% MP120, 5% MP210, 16% DP210, 24% DP450, 22% DSTAY, 3% DPE365, 3% DPE450, and 9% DAOL. Since DIPP (age at first calving) and DAOL (ribeye area) were not available in the auction's catalog, our dataset does not include them.

2.3. Nellore Purebred Model

Physical, morphological, and genetic characteristics make Nellore purebred bulls a heterogeneous product. To investigate such goods, the literature considers the price paid as the sum of the monetary value of the product's characteristics, following Ladd (1978). The hedonic method is a well-established approach to assess the value of traits and their effects on sale prices. Seminal work by Lancaster (1966), Rosen (1974), and Ladd and Martin (1976) provides a theoretical hedonic price framework to investigate livestock price determinants.

Nellore purebred bull prices reflect supply and demand in a specific market—in this case, an auction—and point in time. In each auction, the number of lots offered is fixed; in the short run, therefore, the supply function is inelastic, and the demand function varies only by the value of different lot characteristics (Faminow & Gum, 1986). The benefit of using the hedonic approach is that the framework captures the value of distinct lot characteristics. As a result, researchers have employed the hedonic method to model either commercial cattle (e.g., Schroeder et al. (1988), Williams et al. (2012), Zimmerman et al. (2012), Schulz et al. (2015), Mallory et al. (2016)) or purebred herd (e.g., Dhuyvetter et al. (1996), Chvosta et al. (2001), Jones et al. (2008), Vanek et al. (2008), Vestal et al. (2013), Mitchell et al. (2018)) prices as a function of market, physical, morphological, and genetic traits.

Guided by previous literature on livestock price determinants, especially the one about seedstock, our conceptual model splits lot characteristics into four categories:

physical (P), morphological (MP), genetic (G), and market (M). The Nellore purebred model can be generally written as

$$Price_{it} = \sum_k a_{ikt} P_{ikt} + \sum_l b_{ilt} MF_{ilt} + \sum_m c_{imt} G_{imt} + \sum_h d_{ht} M_{ht} \quad (2.1)$$

where i is the individual lot sold at time t; k, l, m are specific physical, morphological, and genetic traits, respectively; h is a market factor; $a, b,$ and c are the marginal value of purebred Nellore traits k, $l,$ and m, respectively; and d is the marginal effect of market factor h (adapted from Schroeder et al. (1988)). According to equation 2.1, the price of each lot corresponds to the sum of the marginal implicit values of each trait multiplied by the amount of the variable (Ladd & Martin, 1976; Schroeder et al., 1988).

Implementing a similar approach as Mitchell et al. (2018) and Williams et al. (2012), we estimate two hedonic empirical models. The first works with aggregate morphological and genetic indexes in addition to multiple physical and market characteristics.

The second model uses multiple morphological, genetic, physical, and market attributes, allowing us to compare the component weights in indices constructed by animal scientists with the marginal value obtained from the second model. Both hedonic models are estimated with hierarchical mixed-effect structures. Auction location is treated as a random effect, and all other variables are considered fixed effects. Model 1 to be estimated:

$$Log\_Price_i = \beta_0 + \sum_{j=3}^{5} \beta_{1j} EPMURAS_{ij} + \sum_{j=2}^{5} \beta_{2j} MGTe_{ij} + \sum_{j=1}^{10} \beta_{3j} Wt_{ij} + \beta_{4j} SC_i + \sum_{j=1}^{2} \beta_{5j} Age_{ij} + \sum_{j=2013}^{2017} \beta_{6j} Year_{ij} + \sum_{j=1}^{7} \beta_{7j} FarmR_{ij} + \sum_{j=1}^{5} \beta_{8j} LotS_i + \beta_{9j} LotN_i + \sum_{j=1}^{2} \beta_{10j} AucT_{ij} + \mu_{s(i)} + \varepsilon_i. \quad (2.2)$$

where i denotes each sale lot observation, $\mu_{s(i)}$ is the random effect of each auction location, and ε_i is the random error term for each lot. The EPMURAS and MGTe indices are presented in the sale catalog with a star classification ranging from 2 to 5. Each of these indices represents a dummy variable that captures the star categories. Scrotal circumference is a continuous variable, as in Vestal et al. (2013). Table 2 - 2 describes the variables.

Table 2-2 Definition of Variables Used in the Pure-bred Nellore Hedonic Model

Variable	Definition
$\ln(Price)_i$	Natural log of inflation-adjusted prices
Physical characteristics	
Age_{ij}	Binary variables for Age j =1,2: 1 <=27 months, and 2 > 27 months. Base: > 27
Wt_{ij}	Binary variables for weight j =1,…,10: 1 <1,200, 2 = 1,201–1,300, 3 = 1,301–1,400, 4 = 1,401–1,500, 5 = 1,501–1,600, 6 = 1,601–1,700, 7 = 1,7001-1,800, 8 = 1,801-1900, 9 = 1,901-2,000, and 10 >2,000. Base: 1,501–1,600
SC_i	Scrotal Circumference (cm)
Morphological characteristics	
E_{ij}	Structure quality index, $j = 3, 4, 5, 6$;
P_{ij}	Precocity quality index, $j = 3, 4, 5, 6$;
M_{ij}	Muscling quality index, $j = 3, 4, 5, 6$;
U_{ij}	Navel quality index, $j = 1, 2$;
R_{ij}	Conformation quality index, $j = 2, 3, 5$;
A_{ij}	Soundness of feet and legs quality index, $j = 2, 3, 5$;
S_{ij}	Reproductive soundness quality, $j = 2, 3, 5$;
$EPMURAS_{ij}$	Binary variables for EPMURAS morphological quality index score

Table 2-2 Continued

Variable	**Definition**
	$j = 3, 4, 5$; 3 = 25 – 28, Good; 4 = 29 – 31, Very Good; 5 = 32 – 34, Excellent. Base = Good
Genetics characteristics	
MGT_{ij}	Binary variables for Total Genetic Merit (MGT) Index $j = 2, \ldots, 5$; 2 = 31 - 50%, Regular; 3 = 16 - 30%, Good; 4 = 06 - 15%, Very Good; 5 = 0.1 - 5%, Excellent. Base: Very Good
$\mathrm{MP120}_i$	EPD-predictor of maternal body weight at 120 days of age (percentile)
$\mathrm{DP210}_i$	EPD-predictor of body weight at 210 days of age (percentile)
$\mathrm{DP450}_i$	EPD-predictor of body weight at 450 days of age (percentile)
$\mathrm{DPE365}_i$	EPD-predictor of scrotal circumference at 365 days of age (percentile)
$\mathrm{DPE450}_i$	EPD-predictor of scrotal circumference at 450 days of age (percentile)
DSTAY_i	EPD-predictor of stayability (percentile)
$\mathrm{D3P}_i$	EPD-predictor of probability of precocious calving (percentile)
Marketing Factors	
$Year_{ij}$	Year $j = 2013, \ldots, 2017$; Base: 2013
$FarmR_{ij}$	Binary variables for farm reputation $j = 1, \ldots, 7$; 1 = Farm A; 2 = Farm B;…; 7 = Farm G. Base: Farm D
$LotS_{ij}$	Number of heads in a lot (head); $j = 1, \ldots, 5$;
$LotN_i$	Lot number (a proxy for order)
$AucT_{ij}$	Binary variables for auction type $j = 1, 2$; 1 = Virtual; 2 = Virtual and Physical
LOC_{ij}	Binary variables for location $j = 1, \ldots, 4$; 1 = Barra do Garca; 2 = Barreiras; 3 = Jau; and 4 = Uberaba. Base: Barra do Garca

We assign indicator variables for weight and age since they may not have a linear effect on price. Some investigations have tested the linear and quadratic forms of these variables and observed nonlinear relations with the price (Jones et al., 2008; Mallory et al., 2016; Schulz et al., 2015; Williams et al., 2012; Zimmerman et al., 2012). Weight is divided into ten categories of 100 pounds, as suggested by Mitchell et al. (2018). Age has two classes, above and below 27 months. The Brazilian breeding season generally occurs from October to February. Our database makes it clear that the lots sold at auction come from breeding stations 2 or 3 years ago. The age dummy captures this pattern.

Year, lot size, and farm reputation are categorical variables. Our lot size ranges from 1 to 5. Other researchers used a continuous variable for lot size, but their range is considerably larger (Mallory et al., 2016; Schulz et al., 2015; Williams et al., 2012; Zimmerman et al., 2012). For example, Mallory et al. (2016) used a range of 1 to 315 for lot size. The purebred bull literature only considers individual lots (Dhuyvetter et al., 1996; Jones et al., 2008; Vanek et al., 2008; Vestal et al., 2013). Farm reputation is a categorical variable for the seven different seller names/brands that appear in the sales catalog. Schulz et al. (2015) worked with 190 sellers, while for Williams et al. (2012), reputation is the seller announcement (or not).

The lot number is a proxy for sale order because the lots do not necessarily enter in the expected order. Although all auctions were broadcast via satellite and collected bids countrywide, some had physical animals and bidders present during the event while others did not have a physical event. Auction type is a binary variable that captures these two distinct sales features. Auction place is a categorical variable that corresponds with cattle location during the auction and where they were sent from.

Model 2 differs from Model 1 on morphological and genetic variables. Rather than estimating the impact of the indices, we estimate the impact of the index components:

$$Log\_Price_i = \beta_0 + \beta_{1j}E_i + \beta_{2j}P_i + \beta_{3j}M_i + \beta_{4j}U_i + \beta_{5j}R_i + \beta_{6j}A_i + \beta_{7j}S_i + \beta_{8j}MP120_i + \beta_{9j}DP210_i + \beta_{10j}DP450_i + \beta_{11j}DPE365_i + \beta_{12j}DPE450_i + + \beta_{13j}DSTAY_i + \beta_{14j}D3P_i + \sum_{j=1}^{10}\beta_{15j}Wt_{ij} + \beta_{16j}SC_i + \sum_{j=1}^{2}\beta_{17j}Age_{ij} + \sum_{j=2013}^{2017}\beta_{18j}Year_{ij} + \sum_{j=1}^{7}\beta_{19j}FarmR_{ij} + \sum_{j=1}^{5}\beta_{20j}LotS_i + \beta_{21j}LotN_i + \sum_{j=1}^{2}\beta_{22j}AucT_{ij} + \mu_{s(i)} + \varepsilon_i. \quad (2.3)$$

Both hedonic models are estimated with maximum likelihood using the MIXED procedure in STATA. The robust standard errors (Huber–White estimators) are estimated with the Robust command to control for heteroscedasticity. Multicollinearity was tested in the models using the Variation Inflation Factor (VIF)[1]. Farm categories F and G presented values in disagreement with the standard threshold of ten. The baseline lot has the following characteristics: EPMURAS regular, MGTe regular, weight of 1,501–1,600 lb, over 27 months of age, lot size of two head, year 2013, sold by Farm A in a virtual auction.

2.3.1. Results

Table 2 - 3 reports the parameter estimates for the Nellore hedonic model. A likelihood ratio test rejects the linear–linear model in favor of the log–lin model at the 5% level; AIC/BIC tests confirm this result. Most of the characteristics are significant at the 5% level. Estimates represent premiums and discounts for all variables. Model 1

[1] STATA mixed-model performance does not support a VIF test. Instead, we run OLS regression for both models and performed the VIF test.

works with overall indexes (EPMURAS and MGTe). Model 2 adds the results for index components.

Table 2-3 Parameters Estimates for Hedonic Pricing Model

Dependent Variable:		**Log of real Prices**		
		Model 1		Model 2
Lot Characteristics		Estimate		Estimate
	32 - 34 Excellent	0.210**	E	-0.0232
EPMURAS	29 - 31 Very Good	0.0868	P	0.0465**
	25 - 28 Good	0.0257	M	0.00830*
	20 - 24 Regular	base	U	0.000981
			R	0.0337***
			A	0.0501*
			S	0.0407***
	0.1 - 5% Excellent	0.0617**	D3P	0.000554*
	06 - 15% Very Good	-0.00883	DSTAY	-0.000867**
MGTe	16 - 30% Good	0.0155	DPE450	-0.000217
	31 - 50% Regular	base	DPE365	0.000288
	100 - 51% Inferior	0.0211	DP450	-0.000714***
			DP210	-0.000346**
			MP120	-0.00107***
	<1,200	-0.112**		-0.222**
	1,201–1,300	-0.0950***		-0.184*
	1,301–1,400	-0.121***		-0.160***
Weight	1,401–1,500	-0.0494***		-0.0489*
	1,501–1,600	base		base
	1,601–1,700	0.0269*		0.0418
	1,701-1,800	0.0322		0.0523***
	1,801-1900	0.161***		0.201***
	1,901-2,000	0.219***		0.237***
	>2,000	0.384***		0.382***
SC		0.0149***		0.0159***
Age	<=27 months	0.0860***		0.0209*
	> 27 months	base		base

Table 2-3 Continued

Dependent Variable:		**Log of real Prices**	
Year	2013	base	base
	2014	-0.0481***	-0.0678***
	2015	0.353***	0.500***
	2016	0.279***	0.260***
	2017	0.19	0.173
Lot size	1	0.0763**	0.125***
	2	base	base
	3	-0.000816	0.00658
	4	-0.0543**	0.03
	5	-0.0476	-0.0184
Lot number		-0.000468	-0.000357
Farm	A	base	base
	B	0.197	
	C	0.456***	0.369**
	D	0.456***	0.311*
	E	0.455***	0.391**
	F	0.381***	0.222
	G	0.587***	0.397**
Auction Type	1	base	base
	2	0.160***	0.180*
Intercept		7.765***	7.486***
Random effect variance		0.00172	0.0024753
Variance of error term		0.0288	0.288069
N		1,275	982

Notes: Single, double, and triple asterisks (*, **, ***) indicate significance at the 10%, 5%, and 1% level, respectively. (a) Robust standard errors.

2.3.2. Effect of Morphological Characteristics

Most morphological characteristics are statistically significant in determining the price of purebred Nellore lot. An “excellent” EPMURAS index classification is worth a substantial premium for auctioned bulls. Brazilian markets pay more for lots that exhibit precocity, muscling, breed conformation, correct set of feet and legs, and reproductivity soundness quality.

Lots with an “excellent” EPMURAS morphological index receive, on average, a premium of R$551, 23.4% above the base lot price (see Table 2 - 3, Model 1). No statistical significance was found for other classification levels, although the coefficient has the expected sign. This finding may be due to buyers not clearly recognizing the differences among “good,” “very good,” and “regular” lots, confounding the categorization.

Model 2 of Table 2 - 3 breaks down the EPMURAS index by its components. In the second model, two traits are not statistically significant: structure (E) and navel quality (U). To explain cattle price differential, working with breeds other than Nellore, Avent et al. (2004) and Bulut and Lawrence (2007) show frame to be significant, while Zimmerman et al. (2012) and Williams et al. (2012) do not find these characteristics to be significant.

The marginal premiums paid for conformation (R) and the soundness of feet and legs (A) were 3.4% and 5.1%, respectively. Dhuyvetter et al. (1996) report a conformation marginal premium at least two times that of than correctness, contrasting our results. Each incremental increase in precocity and reproductivity soundness score leads to an appreciation of 4.8% and 4.2%, respectively.

In the EPMURAS index, structure (E), precocity (P), and muscling (M) each have a weight of 6/34; navel quality (U), conformation (R), soundness of feet and legs (A), and reproductive soundness (S) have weights of 4/34. Although the morphological index uses the same weight for E, P, and M, we find precocity (P) to be the most relevant trait. At the same time, R, A, and S are statistically significant, while structure (E) is not. Further research should establish an index that reflects the implicit value of each attribute.

Comparing “excellent” and “regular” lots in both indices reveals higher premiums for the morphological index: EPMURAS (+23.4%) and MGTe (+6.4%). However, this result has not previously been described in the literature. We, therefore, suggest that the market pays more for visual characteristics than for genetic information. This finding may be somewhat limited by how the index is categorized.

Overall, our analysis of morphological variables shows that Brazilian cattle buyers look for precocious animals with recommended breed conformation. Body weight traits at standard ages are routinely measured on Brazilian farms and are the most common selection goals in the country (Paterno et al., 2017). Producers can add value to their lots with visual scores once the results show that the market pays not only for weight but also for weight composition. Moreover, adding visual scores to the selection process is not costly and can be done at the same time as weight measurement (Paterno et al., 2017).

2.3.3. Effect of Genetic Characteristics

Genetic traits are statistically significant for describing price changes in Nellore auctions. Breeders categorized as “excellent” in the MGTe index received higher premiums. EPDs for milk, stayability, and weight were the most relevant genetic traits in determining animal value.

The results in Table 2 - 3 indicate that the MGTe index explains variations in Nellore prices. According to Model 1, lots classified as “excellent” receive a 6.4% premium compared with the base lot, an increase of R$149.94 over the base price. Model 2 displays the findings obtained from the MGTe components.

Contrary to expectation, there is no evidence that the EPD for scrotal circumference (at either 365 and 450 days of age) influences lot prices. No associations were found in the literature between scrotal circumference and price. One of the main characteristics associated with the reproductive performance of males is the testicular volume (Martínez-Velázquez et al., 2003). Scrotal circumference and age at first calving are inversely correlated for either Nellore (Gressler et al. (2000)) or Angus (Notter et al., 1993). Fertility is one of the main reasons for the Nellore breed’s success in Brazil (Lobo et al., 2000). However, stayability, the probability of cow producing at least three calves before reaching 76 months of age, is statistically significant in explaining lot prices.

Consistent with some literature, we found premiums related to the EPD that captures the effect of mother’s milk in offspring weight. A 1-standard-variation deviation upward in MP120 EPD is associated with a 2.3% premium above the base lot. Jones et al. (2008), investigating two models, list statistically significant premiums for milk EPD (0.5% and 0.7%) for Angus cattle. Dhuyvetter et al. (1996) also report premiums for milk EPDs of 0.8%–2.8% when examining seven taurine breeds, but only three of these were significant. However, Vestal et al. (2013) did not find evidence of weaning weight due to milk production explaining price.

EPD for body weight (at 210 and 450 days of age) influences lot prices. A 1-standard-deviation variation in body weight corresponds to premiums/discounts of only 0.6% and 0.9% for DP210 and DP450, respectively. Several prior studies have noted the importance of weaning weight (Vestal et al. (2013), Vanek et al. (2008), and Dhuyvetter et al. (1996)), whereas one investigation did not observe statistical significance for weaning weight (Jones et al., 2008).

Some EPDs that comprise the MGTe index do not explain variations in Nellore prices, while others have a small impact. One possible explanation for this might be that auction buyers are just looking for “excellent” animals, since the MGTe index summarizes the main characteristics weighted by specialists. Another possible explanation is buyers’ lack of knowledge about how to use EPDs appropriately as a selection tool. As a result, the latter ends up buying the breeder based on the index rather than purchasing a specific animal to meet the needs of his herd.

To construct an economic genetic index, our findings in Table 2 - 3 suggest we should use slightly different weights for EPDs than those used by ANCP. According to our results, EPDs for stayability and milk should receive more emphasis. The Brazilian breeder program gives 22% and 8% to these traits, respectively. To ANCP, growth (EPDs for weight gain) receives more weight, 40%. Caution is needed here since this intriguing contrast could be because of buyer profiles and the heritability of each MGTe component.

Buyers’ farm operations may have different endpoints. Cow-calf producers that sell calves at weaning are concerned about weaning-weight EPD while fattening farmers who sell steers to the slaughterhouses are concerned about growth and carcass EPDs. Aligning operation endpoints and index market endpoints is essential to enterprise profitability. Different programs have developed a selection index for use by seedstock and commercial producers (Weaber, 2016). For instance, Angus has four indices: W (weaning), F (feedlot), G (grid), and B (beef).

Future research should investigate how different buyer profiles and characteristics (e.g., breeder producer, commercial farmer, operation size) affect marginal value estimations of genetic and morphological characteristics. Further work is also needed to evaluate the impact of birth weight EPD on the price of Nellore cattle. Birth weight is statistically significant in explaining variations in Angus price. Failure to control for birth weight can lead to calving problems in the herd. Birth weight is also correlated with weaning and yearling weight. The producer, whose goal is only to maximize MGTe, may have future calving problems since EPDs for weight make up 40% of the MGTe index.

2.3.4. Effect of Physical Characteristics

All three physical variables investigated explain variations in Nellore prices. Heavier animals with a larger scrotal circumference are more valued. Younger animals also received higher bids. There is consistency between the results from Model 1 and Model 2. Model 2 comes from a regression with fewer observations since one farm did not report specific EPDs.

Weight has a positive impact on price in both models. In Model 1, sires weighing 1,301–1,400 lb receive a discount of 11.4% (R$ 268.07) compared with lots of 1,501–

1,600 lb. Lots weighing 1,901–2,000 lb receive a premium of 24.5% (R$ 578) compared to lots of 1,501–1,600 lb.

An increase in scrotal circumference (SC) implies a high average lot price. In either model, we reject the null hypothesis at the 5% level that SC does not affect the log of prices. In Model 1, a 1-centimeter increase in SC receives a premium R$35.44. Model 2 predicts a premium of R$28.54 for each additional 1 cm of SC. However, these results have not previously been described. Vestal et al. (2013) found that CS does not affect prices for purebred Angus bulls.

What stands out in the physical characteristics is the effect of age. Interestingly, young bulls receive premiums relative to older bulls in both models. In Model 1, animals under 27 months of age receive a premium of 9.0% (R$211.64) compared to lots above this age threshold. This outcome is contrary to that of Jones et al. (2008), Chvosta et al. (2001), and Dhuyvetter et al. (1996), who find that buyers pay a premium for older bulls but at decreasing rate.

The contrast may be partly explained by the difference in the average age of lots sold in Brazil and the United States. In the studies mentioned previously, the average age of the animals is approximately 14 months, with a range of 10–37 months; in Brazil, the average age is 31 months, with a range of 20–58 months. Given that Brazilian auctioned bulls are fit for reproduction and have a genetic profile, buyers will probably be looking for breeders that will work in their herd for a longer time, so they end up choosing younger bulls.

2.3.5. Effect of Market Factors

Market factors are statistically significant in explaining prices of auctioned Nellore sold at auction. The variation of years affects the appreciation of Nellore seedstock. Animals sold in smaller lots receive higher offers. Both farm reputation and auction type help explain the final bid on the lots. Both models present similar results. The findings provide valuable insights into the role of market factors in pricing livestock lots.

Auction year significantly influences the price of the Nellore's lot. Brazil suffered a severe economic crisis and political turmoil from 2014 to 2017. During this period, the country’s real gross domestic product (GDP) shrank by 5.51% (World Bank, 2018), and a president was impeached. Despite that, Brazil hosted and lost the 2014 FIFA World Cup, which took place in the same season as the auctions. Despite the economic recession and political riots, lots of purebred Nellore prices appreciated compared to 2013. For instance, cattle sold in 2015 received a premium of R$995.95 (42.3%) relative to 2013, as shown in Table 2 - 3 (Model 1). This result may reflect the increasing demand for genetically proven superior animals given the professionalization of commercial beef production in the country. 2014 was an exception, with the lots depreciating.

Lot size significantly alters prices for Nellore cattle. Individual lots receive a premium of R$186.75 (7.9%) relative to lots of two animals. Larger lot sizes receive discounts. This result is contrary to previous studies, which have suggested that the impact of lot size increases at decreasing rate (e.g., Mallory et al. (2016), Schulz et al.

(2015), Zimmerman et al. (2012)). These contrasts must be interpreted with caution since the studies mentioned examine commercial cattle, and our research investigates purebred livestock. Commercial cattle auctions usually have larger lots (e.g., lot size in Mallory et al. (2016) ranges from 1 to 315), while lot size in our investigation ranges from 1 to 5.

The proxy for the order of entrance does not significantly impact Nellore prices. Caution is needed here since the variable “lot number” is just a proxy for an order of entrance. The database provider pointed out that it is not uncommon for animals to enter out of the lot number sequence. According to the literature, the selling price is lower for lots sold later in each auction than those placed near the beginning. (Vanek et al. (2008), Jones et al. (2008), Dhuyvetter et al. (1996))

Farm reputation is associated with a statistically significant impact on Nellore prices. As shown in Table 2 - 3 (Model 1), lots from farms C, D, E, F, and G receive premiums of 57.7%, 57.8%, 57.6%, 46.3%, and 79.8%, respectively, relative to Farm A. These findings highlight the potential usefulness of branding strategies for producers. These results further support the work done by Chvosta et al. (2001) and Jones et al. (2008) on seller reputation as a relevant driver of prices for seedstock bulls. Schulz et al. (2015) and Turner et al. (1993) show that the seller reputation likely exists for some commercial producers. These results differ from findings reported by Williams et al. (2012).

Auction type statistically dictates the Nellore price sold in Brazilian auctions. Lots sold in auctions broadcast live with a collection of bids on the premises and by phone receive a R$409.52 (17.4%) premium relative to auctions only broadcast with videos of lots recorded and bids collected by phone. This outcome is contrary to that of Bailey and Peterson (1991), who did not find structural price differences between traditional and satellite video auctions.

2.4. Conclusion

This research extends the knowledge about livestock markets, addressing the influence of morphological, genetic, physical, and market factors on the price of purebred Nellore cattle sold at auction in Brazil. A unique dataset highlighted higher premiums for the morphological index than for the genetic index, a result not previously documented in the literature, and particularly relevant given the emphasis breeders' associations have placed on genetic attributes.

Our results show cattle buyers' preferences for precocity. U.S. farmers can expect a more productive Brazil, steers finishing early and heifers calving early. Policymakers can observe the country emulating the U.S. path to modern cattle operations. Our findings suggest strategies for producers. The choice (often neglected by many breeders) of lot size, auction type, and advertising (reputation) adds value to the bulls. Cattle operations goals should involve genetics and morphological factors since visual scores and EPDs explain variations in prices. Younger, heavier animals and with a larger scrotal circumference are more valued. Buyers can use the finding as a benchmark to evaluate their investments.

The current study only considered the context of purebred cattle. However, these results may not pertain to commercial livestock. Future research might explore this segment of Brazil's beef supply chain. Purebred farms and commercial farms buy purebred bulls. Thus, it would be interesting to compare how each of these two distinct groups values each lot attribute. Further study could also add carcass EPDs measures to our model.

2.5. References

ANCP. (2018). MGTe (Mérito Genético Total Econômico). Retrieved from http://www.ancp.org.br [Accessed February 18, 2018]

Avent, R., Ward, C., & Lalman, D. (2004). Market Valuation of Preconditioning Feeder Calves. *Journal of Agricultural and Applied Economics, 36*(1), 173-183. doi:10.1017/S1074070800021933

Bailey, D., & Peterson, M. C. (1991). A Comparison of Pricing Structures at Video and Traditional Cattle Auctions. *Western Journal of Agricultural Economics, 16*(2), 392-403.

Bailey, D., Peterson, M. C., & Brorsen, B. W. (1991). A Comparison of Video Cattle Auction and Regional Market Prices. *American Journal of Agricultural Economics*, *73*(2), 465-475. doi:Doi 10.2307/1242731

Blank, S. C., Saitone, T. L., & Sexton, R. J. (2016). Calf and Yearling Prices in the Western United States: Spatial, Quality, and Temporal Factors in Satellite Video Auctions. *Journal of Agricultural and Resource Economics, 41*(3), 458-480.

BrasilcomZ. (2018). EPMURAS. Retrieved from http://www.brasilcomz.com/ [Accessed March 8, 2018]

Buccola, S. T. (1980). An Approach to the Analysis of Feeder Cattle Price Differentials. *American Journal of Agricultural Economics*, *62*(3), 574-580. doi:Doi 10.2307/1240218

Bulut, H., & Lawrence, J. D. (2007). The Value of Third-Party Certification of Preconditioning Claims at Iowa Feeder Cattle Auctions. *Journal of Agricultural and Applied Economics, 39*, 625-240.

CEPEA. (2017). PIB do Agronegocio Brasileiro. Retrieved from https://www.cepea.esalq.usp.br/br/pib-do-agronegocio-brasileiro.aspx [Accessed February 21, 2018]

Chvosta, J., Rucker, R. R., & Watts, M. J. (2001). Transaction Costs and Cattle Marketing: The Information Content of Seller-Provided Presale Data at Bull Auctions. *American Journal of Agricultural Economics, 83*(2), 286-301. doi:Doi 10.1111/0002-9092.00156

Dhuyvetter, K. C., Schroeder, T. C., Simms, D. D., Bolze, R. P., & Geske, J. (1996). Determinants of Purebred Beef Bull Price Differentials. *Journal of Agricultural and Resource Economics, 21*(2), 396-410.

Faminow, M. D., & Gum, R. L. (1986). Feeder Cattle Price Differentials in Arizona Auction Markets. *Western Journal of Agricultural Economics, 11*, 156-163.

Koury Filho, W. (2005). *Escores Visuais e suas Relacoes com Caracteristicas de Crescimento em Bovinos de Corte.* [Unpublished doctoral dissertation], Universidade Estadual Paulista, Jaboticabal.

Garrick, D. J., & Ruvinsky, A. (2014). *The Genetics of Cattle* (2nd Edition). Wallingford: CAB International

Gressler, S. L., Bergmann, J. A. G., Pereira, C. S., Penna, V. M., Pereira, J. C. C., & Gressler, M. G. d. M. (2000). Estudo das Associações Genéticas entre Perímetro Escrotal e Características Reprodutivas de Fêmeas Nelore. *Revista Brasileira de Zootecnia, 29*(2), 427-437. doi:https://dx.doi.org/10.1590/S1516-35982000000200016

Jones, R. D., Turner, T., Dhuyvetter, K., & Marsh, T. (2008). Estimating the Economic Value of Specific Characteristics Associated with Angus Bulls Sold at Auction. *Journal of Agricultural and Applied Economics, 40*(01), 315 - 333.

Ladd, G. W. (1978). Research on Product Characteristics: Models, Applications, and Measures. *Research Bulletin (Iowa Agriculture and Home Economics Experiment Station), 36*(584), 37.

Ladd, G. W., & Martin, M. B. (1976). Prices and Demands for Input Characteristics. *American Journal of Agricultural Economics, 58*(1), 21-30. doi:Doi 10.2307/1238573

Lancaster, K. J. (1966). New Approach to Consumer Theory. *Journal of Political Economy, 74*(2), 132-157. doi:Doi 10.1086/259131

Lobo, R. B., Viacava, C., Castanho Filho, E. P., Josahkian, L. A., Barbosa Jr., N. S., Pineda, N., & de Felicio, P. E. (2000). *Nelore: o Boi Ecologico que esta Conquistando o Mundo*. Sao Paulo Petropolis.

Mallory, S., DeVuyst, E. A., Raper, K. C., Peel, D., & Mourer, G. (2016). Effect of Location Variables on Feeder Calf Basis at Oklahoma Auctions. *Journal of Agricultural and Resource Economics, 41*(3), 393-405.

Martínez-Velázquez, G., Gregory, K., Bennett, G., & Van Vleck, L. (2003). Genetic Relationships Between Scrotal Circumference and Female Reproductive Traits. *Journal of Animal Science, 81*(2), 395-401. doi:10.2527/2003.812395x

Mintert, J., Blair, J., Schroeder, T. C., & Brazle, F. (1990). Analysis of Factors Affecting Cow Auction Price Differentials. *Southern Journal of Agricultural Economics, 22*(2), 23-30.

Mitchell, J. L., Peel, D. S., & Brorsen, B. W. (2018). Price Determinants of Bred Cows. *Journal of Agricultural and Applied Economics, 50*(1), 64-80. doi:10.1017/aae.2017.20

Notter, D. R., McFadden, L. G., & Bergmann, J. A. G. (1993). *Relationship Between Yearling Scrotal Circumference and Measures of Female Reproduction in Angus Cattle.* . Paper presented at the Beef Improvement Federation, Asheville, North Carolina.

Parcell, J. L., Franken, J. R. V., Cox, M., Patterson, D. J., & Randle, R. F. (2010). Buyers' Perceptions of Importance and Willingness-to-Pay for Certain Attributes of Source and Production Verified Bred Heifers. *Agricultural Economics, 41*(5), 463-470. doi:10.1111/j.1574-0862.2010.00458.x

Parcell, J. L., Schroeder, T. C., & Hiner, F. D. (1995). Determinants of Cow-Calf Pair Prices. *Journal of Agricultural and Resource Economics, 20*(2), 328-340.

Paterno, F., Buzanskas, M., Koury Filho, W., Lôbo, R., & Queiroz, S. (2017). Evaluation of Body Weight and Visual Scores for Genetic Improvement of Nelore Cattle. *Tropical Animal Health and Production, 49*(2), 467-473.

Rosa, A. d. N. F., & Menezes, G. R. d. O. (2016). Papel do Zebu na Pecuária de Corte Brasileira. Retrieved from https://www.embrapa.br/en/busca-de-noticias/-/noticia/9523901/artigo-papel-do-zebu-na-pecuaria-de-corte-brasileira [Accessed September 10, 2018]

Rosen, S. (1974). Hedonic Prices and Implicit Markets - Product Differentiation in Pure Competition. *Journal of Political Economy, 82*(1), 34-55. doi:Doi 10.1086/260169

Schroeder, T., J., Mintert, F., Brazle, & Grunewald., O. (1988). Factors Affecting Feeder Cattle Price Differentials. *Western Journal of Agricultural Economics, 13*, 71-81.

Schulz, L. L., Dhuyvetter, K. C., & Doran, B. E. (2015). Factors Affecting Preconditioned Calf Price Premiums: Does Potential Buyer Competition and Seller Reputation Matter? *Journal of Agricultural and Resource Economics, 40*(2), 220-241.

Turner, S. C., McKissick, J., & Dykes, N. S. (1993). Reputation Selling in Feeder Cattle Teleauctions. *Applied Economic Perspectives and Policy, 15*(1), 9-19. doi:10.2307/1349708

USDA. (2018). Foreign Agricultural Service. Retrieved from https://apps.fas.usda.gov/psdonline/app/index.html#/app/downloads [Accessed February 19, 2018]

Vanek, J. K., Watts, M. J., & Brester, G. W. (2008). Carcass Quality and Genetic Selection in the Beef Industry. *Journal of Agricultural and Resource Economics, 33*(3), 349-363.

Vestal, M. K., Lusk, J. L., De Vuyst, E. A., & Kropp, J. R. (2013). The Value of Genetic Information to Livestock Buyers: a Combined Revealed, Stated Preference Approach. *Agricultural Economics, 44*(3), 337-347. doi:10.1111/agec.12016

Weaber, R. (2016). Beef Cattle Economic Selection Indices. Retrieved from https://articles.extension.org/pages/73372/beef-cattle-economic-selection-indices [Accessed April 08, 2018]

Williams, G. S., Raper, K. C., DeVuyst, E. A., Peel, D., & McKinney, D. (2012). Determinants of Price Differentials in Oklahoma Value-Added Feeder Cattle Auctions. *Journal of Agricultural and Resource Economics, 37*(1), 114-127.

World Bank. (2018). GDP growth (annual %). Retrieved from https://data.worldbank.org/ [Accessed November 11, 2018]

Zimmerman, L. C., Schroeder, T. C., Dhuyvetter, K. C., Olson, K. C., Stokka, G. L., Seeger, J. T., & Grotelueschen, D. M. (2012). The Effect of Value-Added Management on Calf Prices at Superior Livestock Auction Video Markets. *Journal of Agricultural and Resource Economics, 37*(1), 128-143.

3. EU – MERCOSUR FREE TRADE AGREEMENT: IMPLICATIONS FOR AGRICULTURE

3.1. Introduction

In 2019, the Southern Common Market (Mercosur) and the European Union (EU) signed a free-trade agreement (FTA) (not yet ratified). The two blocs together accounted for 47.96% of world agricultural export value in 2016 (FAO, 2019). Because of the relevance of the countries involved in the negotiations, the EU–Mercosur FTA may affect international agricultural trade prices and volumes, but—to our knowledge—no investigation has addressed these impacts.

This paper attempts to quantify the possible effects of an EU–Mercosur FTA on agricultural markets. We develop a gravity model of international trade in a general equilibrium framework to investigate the effects of the FTA on selected agricultural products: chicken, cattle, pig, cotton, soybean, wheat, and maize. This study tests the hypothesis that EU tariff barriers cause trade distortions for Mercosur agricultural exports and that an FTA will generate gains to both Mercosur and the EU due to the increase in trade in agricultural products.

After 20 years of negotiations, the EU and Mercosur signed the FTA. Mercosur had been losing the European agricultural market: Mercosur agricultural exports to the EU shrank 22% from 2013 to 2017, while EU exports to Mercosur fell 9% in the same period (CHRTD, 2019). The flow of agricultural products from Mercosur to the EU is greater than vice versa. For example, in 2017, Mercosur shipped US$22.4 billion in agricultural products to and imported $1.5 billion from the EU (CHRTD, 2019).

Josling et al. (2015), Grossman (2016), and Martin (2018) agree that the research problem is worth studying because of (i) the implications of the FTA for worldwide agriculture, especially Latin America, (ii) future policy developments, and (iii) lack of knowledge about the implications of an FTA on agricultural trade using newly developed methodologies.

Looking at agriculture, Josling et al. (2015) summarized Latin America's role in FTAs. Although many FTAs have been established since the 1980s, the Mercosur countries—Argentina, Brazil, Paraguay, and Uruguay—have not been a part of the wave of bilateral and regional trade liberalization. Despite the region's agricultural potential and relevance (Calil and Ribera (2019), Durand-Morat (2019)), the Mercosur countries have a relatively closed economy. In 2016, the average applied tariff rates on primary products were higher in Argentina (7.5%), Brazil (8.5%), Paraguay (5.9%), and Uruguay (6.8%), than in the EU (5.3%) and the United States (2.5%) (World Bank, 2019).

Grossman (2016) argued that a trade agreement provides a way for nations to internalize international externalities. Externalities in the agricultural sector may lead to a lack of food security and higher food prices and volatility for consumers (Josling et al., 2015). Further, trade distortion in agriculture is exceptional relative to other sectors (Trebilcock & Pue, 2015). Countries accede to trade agreements to address externalities that appear in competitive markets regardless of their government objectives. Martin (2018) pointed out that future research in agricultural trade should involve both forecasting and "what-if" policy analysis under the gravity framework, emphasizing that trade is poorly understood relative to other areas of interest to agricultural and applied economists.

The gravity model is the most suitable method to answer our research problem because of its recent theoretical developments and empirical success. According to Heid and Larch (2016), the gravity model is the appropriate approach to conjecture about the welfare effects of counterfactual trade liberalization scenarios in a general equilibrium framework. Echoing Newton's Law of Gravity, the gravity model of international trade predicts that the international trade (gravitational force) between two countries (particles) is proportional to their sizes (masses) and inversely proportional to their trade frictions (the square of distance) (Yotov et al., 2016). To Allen et al. (2020), a universal gravity framework encompasses trade models with the equilibrium satisfying the following conditions: (i) "iceberg"-type bilateral trade frictions; (ii) a constant elasticity of substitution (CES) aggregate demand function; (iii) a CES aggregate supply function; (iv) market-clearing; (v) balanced trade; and (vi) a choice of the numeraire.

The theoretical developments of gravity models are rooted in Anderson (1979) study of multilateral price effects for trade flows, assuming product differentiation by place of origin and Constant Elasticity of Substitution (CES) expenditures. However, it was the theoretical foundations of Eaton and Kortum (2002) and Anderson and van Wincoop (2003) that allowed gravitational models to flourish in the literature. Eaton and Kortum (2002) presented the gravity model on the supply side as a Ricardian structure by investigating the comparative advantages and geographic effects on bilateral trade.

Anderson and van Wincoop (2003) discussed the importance of trade costs (multilateral resistance) and the proper empirical comparative static analysis.

Because gravity models embrace different micro-foundations, this approach is widely accepted to tackle trade policy inquiries. For instance, Yotov et al. (2016) pointed out that gravity models span alternative micro-foundations, such as a single economy model with monopolistic competition (Anderson and van Wincoop (2003)), the Heckscher–Ohlin approach (Deardoff (1998)), a Ricardian framework (Eaton and Kortum (2002)), a heterogeneous firm model (Chaney (2008)), a sectorial Armington framework (Anderson et al. (2016)), and a sectorial Ricardian model (Costinot and Donaldson (2012)). Allen et al. (2019) also established the power of the gravity approach to international trade in a study that proved sufficient conditions for the existence and uniqueness of trade equilibrium for a large class of general equilibrium and economic geography trade models. Further, Arkolakis et al. (2012) revealed that a large class of international trade models leads to isomorphic gravity equations that help to explain the gains from trade.

Gravitational models express their versatility in empirical applications. Head and Mayer (2014) offered representative estimates and evidence for the empirical success of gravity with aggregate data. Anderson and Yotov (2010) presented sectoral gravity estimates with goods trade. Anderson et al. (2018) demonstrated that gravity works with services sectoral data. Aichele et al. (2016) estimated sectoral gravity for agriculture, mining, manufacturing goods, and services.

Drawing from empirical gravity literature, Yotov et al. (2016) enumerate six recommendations to obtain a theoretically consistent econometric specification of equilibrium effects of international trade policy: First, panel data should be used whenever possible (Bergstrand & Baier, 2007). Second, panel data with intervals is preferable to consecutive or pooled data (Olivero & Yotov, 2012). Third, the dataset shall contain both intra- and international trade flows (Yotov (2012), Dai et al. (2014), Bergstrand et al. (2015), Heid et al. (2017)). Fourth, time-varying importer and exporter fixed effects should be included to account for unobservable multilateral resistance (Anderson and van Wincoop (2003), Larch and Yotov (2016)). Fifth, the pair fixed effect should be inserted in gravity panel estimations to resolve the endogeneity of trade policy variables and all time-invariant bilateral trade costs (Bergstrand and Baier (2007), Egger and Nigai (2015), Agnosteva et al. (2019)). Sixth, the gravity model should be estimated using Poisson Pseudo Maximum Likelihood (PPML) estimators for accounting for heteroscedasticity and for taking advantage of the information contained in zero trade flows (Silva and Tenreyro (2006), Arvis and Shepherd (2013), Fally (2015), Anderson et al. (2018), Larch and Yotov (2016))

Relatively few published studies have explored agricultural markets under gravity models. To date, the EU–Mercosur FTA has not yet been empirically investigated. We fill this gap in the literature. More closely related to our investigation is Del Fiori (2015), who analyzed a hypothetical EU–Brazil bilateral agreement with a gravity model, considering the following products: frozen beef, fresh beef, chicken, pork, raw sugar. The authors estimated the FTA coefficient for each of these commodities under Ordinary Least Squares and PPML without observing the effects on trade and welfare.

Our research adds to the literature by providing the price and welfare effects in a general equilibrium set up. In contrast to Del Fiori (2015), we incorporate intra- and international trade data in a panel framework with three-year intervals (following the recommendations mentioned above). Moreover, our study is one of the first investigations of agricultural markets to include intranational data and pair fixed effects.

Two related investigations concerned the North American Free Trade Agreement (NAFTA) and a hypothetical US–EU trade agreement. Ghazalian (2017) employed a gravity model to evaluate the effects of NAFTA and Canada–the United States Free Trade Agreement (CUSFTA) on agricultural trade flows for disaggregated agricultural product categories. With a data range from 1964 to 2013, the author employed exporter-by-year and importer-by-year specific effects to estimate the impact of FTA using different econometric methods.

Arita et al. (2017) combined sector-level econometric modeling with an agriculture-focused computable generable equilibrium (CGE) model to simulate two liberalization scenarios on the US–EU agri-food trade. The researchers estimated the gravity model using data from 2010–2012 without intranational flows or pair fixed effects. The CGE model includes Brazil, Canada, China, the EU, India, Mexico, the United States, and the rest of the world regions.

Another strand of literature concerns trade costs and productivity. Tombe (2015) applied a gravity model to capture the interaction between trade costs and productivity differentials between agriculture and other sectors in developing countries. Heerman et al. (2015) used the gravity model to estimate agricultural trade costs in the Asia-Pacific region and assess the implications of different regional trade initiatives in that region. Costinot and Donaldson (2016) used the gravity model together with Global Agro-Ecological Zones (GAEZ) data to assess the productivity gains from increased agricultural trade within the United States, finding these gains to have the same order of magnitude as those from increases in farm-level productivity.

The next section details the theoretical framework, empirical specification, and data construction. Then we present the results and further implications in the following section. Finally, the last section concludes.

3.2. A Quantitative Framework for Agricultural Trade

This section starts by establishing the theory underlying our agricultural trade model. Besides settling the gravity model foundations, we present the empirical framework specification. Then we summarize the database's characteristics.

3.2.1. Theoretical Gravity Model of International Trade

We develop a gravity model in the vein of Larch and Wanner (2017), Heid and Larch (2016), Donaldson (2018), and Anderson and van Wincoop (2003). The model is described for the demand side; however, it is isomorphic to the supply side, as in Eaton and Kortum (2002).

In our model, country i exports to country j, and N countries produce one variety of goods, differentiated by the country of origin à la Armington (1969). Supply, Q_i, is fixed, and its factory-gate price is p_i. So, for exporter i, the income from domestic production is $Y_i = p_i Q_i$. The constant elasticity of substitution (CES) shapes the importer's utility function U_j, defined as

$$U_j = \left[\sum_i (\alpha_i)^{\frac{1-\sigma}{\sigma}} \left(c_{ij}\right)^{\frac{\sigma-1}{\sigma}}\right]^{\frac{\sigma}{\sigma-1}}, \tag{3.1}$$

where σ is the elasticity of substitution in consumption of commodities from different locations, α_i is the positive exogenous preference parameter (measures the appeal of products from country i for country j), c_{ij} is the consumption of goods in the country i from exporter j. The consumer maximizes the utility function U_j subject to a budget constraint Y_j. The balanced trade assumption in country j requires total production Y_j, equivalent to total expenditure E_j. Denoting country j expenditure by E_j, the budget constraint (total endowment) can be written as

$$E_j = \sum_i p_{ij} c_{ij}, \tag{3.2}$$

where p_{ij} is the delivered price. Moreover, the consumer purchase price, p_{ij}, can be restated as $p_{ij} = p_i t_{ij}$ (i.e., the product of factory-gate prices, (p_i), and iceberg transport costs, $\left(t_{ij} > 1\right)$). We further assume frictionless intranational trade flow $(t_{ii} = 1)$ and symmetric trade costs $(t_{ij} = t_{ji})$. Therefore, solving the consumer optimization problem yields the value of exports from country i to country j:

$$X_{ij} = \left(\frac{\alpha_i p_i t_{ij}}{P_j}\right)^{1-\sigma} E_j, \tag{3.3}$$

where P_j is the CES price index, $P_j = \left[\sum_i \left(\alpha_i p_{ij}\right)^{1-\sigma}\right]^{1/1-\sigma}$, and c_{ij}, the consumption, corresponds to $c_{ij} = \left(p_{ij}\right)^{-\sigma} \left(\alpha_i / P_j\right)^{1-\sigma} E_j$. Equation 3 shows trade flows, X_{ij}, proportional to total expenditure, E_j; that is, ceteris paribus, richer (larger) nation consumes more. Also, equation 3.3 reflects the law of demand, the inverse relationship of trade and prices $\left(p_{ij} = p_i t_{ij}\right)$. Hence, a low price at the farm gate (p_i) and low bilateral trade cost $\left(t_{ij}\right)$ favor bilateral trade. The direct relationship between the CES price index and trade translates the substitution effects across goods from different nationalities, ceteris paribus. The elasticity of substitution (σ) amplifies the oscillation of both farm-gate prices and CES price aggregator.

To establish the market clearance condition, we impose

$$Y_i = \sum_j X_{ij} = \sum_j \left(\frac{\alpha_i p_i t_{ij}}{P_j}\right)^{1-\sigma} E_j.$$

Given the world output, $Y \equiv \sum_i Y_i$, the CES price index, the clearance condition, and equation 3, the structural gravity model is denoted as

$$X_{ij} = \frac{Y_i E_j}{Y}\left(\frac{t_{ij}}{\Pi_i P_j}\right)^{1-\sigma} \tag{3.4}$$

where

$$(\Pi_i)^{1-\sigma} = \sum_j \left(\frac{t_{ij}}{P_j}\right)^{1-\sigma} \frac{E_j}{Y} \tag{3.5}$$

and

$$\left(P_j\right)^{1-\sigma} = \sum_i \left(\frac{t_{ij}}{\Pi_i}\right)^{1-\sigma} \frac{Y_i}{Y}. \tag{3.6}$$

Note that equation 4 decomposes the bilateral trade $\left(X_{ij}\right)$ flows in terms of size $\left(Y_i E_j / Y\right)$ and overall trade cost $\left[\left(t_{ij}/\Pi_i P_j\right)^{1-\sigma}\right]$. The size term implies a large producer exports more, a big/wealthy economy imports more from different sources, and countries about the same size have more trade (Anderson 2011). The overall trade cost is composed of bilateral trade cost (t_{ij}), outward multilateral resistances (eq. 3.5), and inward multilateral resistances (eq. 3.6). According to Anderson and van Wincoop (2003), outward multilateral resistance captures exporter i's ease of market access, and inward multilateral resistance measures importer j's ease of market access.

The gravity system holds each sector (commodity) individually because of the separability property (Yotov et al., 2016). Consequently, the same approach to estimating the aggregate model can be used to estimate each sector (commodity) model separately.

3.2.2. Empirical Framework Specification

Armed with the theoretical foundations of the gravity model, we discuss how to tackle the research problem empirically. The empirical model has five underlying assumptions: First, there is only one sector. Second, the only production factor is labor, L_i. Third, trade corresponds to final goods (i.e., there are no intermediaries). Fourth, linear trade balances (i.e., the trade balance) are an additive component of country expenditure. National expenditure can, therefore, be written as the sum of national trade surplus/deficit and labor income: $E_j = D_j + w_j L_j$. Fifth, the elasticity of substitution for goods from different origins is $\sigma = 3$. Head and Mayer (2014) summarized 32 papers, reporting a median elasticity of 3.19.

According to the best practices in estimating structural gravity model laid out by Anderson et al. (2018) and Larch and Yotov (2016), we empirically investigate equation 4 in a four-step general equilibrium framework: (i) Solve the baseline scenario; (ii)

Define a counterfactual scenario; (iii) Solve the counterfactual model; and (iv) Collect, construct, and report indexes of interest.

To solve the baseline scenario given the theoretical framework and above mention assumptions, the international trade model for each sector is written as in Baier et al. (2019):

$$X_{ij} = \frac{A_i w_i^{-\sigma} \tau_{ij}^{-\sigma}}{\sum_k A_k w_k^{-\sigma} \tau_{kj}^{-\sigma}} E_j \tag{3.7}$$

As discussed previously, X_{ij} is the trade flow from country i to country j, E_j is the total expenditure, A_i is the technological level in the country of origin, w_i is the production cost, and τ_{ij} is the iceberg cost. Following the derivations of Bergstrand and Baier (2007) for panel implementation, equation 3.7 can be rewritten in exponential form:

$$X_{ij,t} = \exp\left(\ln A_{i,t} w_{i,t}^{-\sigma} + \ln \frac{E_{j,t}}{P_{j,t}^{-\sigma}} + \ln \tau_{ij,t}^{-\sigma}\right) + \epsilon_{ij,t}, \tag{3.8}$$

where $P_j^{-\sigma} = \sum_i A_i\, w_i^{-\sigma} \tau_{ij}^{-\sigma}$. Empirically, the trade frictions parameter $\left(ln\tau_{ij,t}^{-\sigma}\right)$ is a function of time-invariant controls and the regional trade agreement (RTA):

$$\ln \tau_{ij,t}^{-\sigma} = \delta C_{ij} + \beta_1 RTA_{ij,t} + u_{ij,t}. \tag{3.9}$$

Biased coefficient estimates may arise from the possible relationship between the unobserved controls $\left(C_{ij}\right)$ and $\left(RTA_{ij,}\right)$. However, Bergstrand and Baier (2007) showed that identifying δ is neither necessary nor sufficient to estimate the RTA effects once using pair fixed effect instead of δC_{ij}. Thus, to estimate the trade costs and the average regional FTA effect, we set up the following baseline model:

$$X_{ij,t} = \exp\left(\pi_{i,t} + \chi_{j,t} + \mu_{ij} + \beta_1 RTA_{ij,t}\right) + \varepsilon_{ij,t}, \tag{3.10}$$

where π_i is the outward multilateral resistance (exporter fixed effects), χ_j is the inward multilateral resistance (importer fixed effects), μ_{ij} is the symmetric pair fixed effects, $RTA_{ij,t}$ is a dummy variable indicating that countries i and j belong to the same trade agreement at time t, and ε_{ij} is the disturbance term. We estimate equation 10 using PPML in a panel dataset with a three-year interval. Silva and Tenreyro (2006) argued that PPML outperforms OLS in gravity equations for trade.

The second step defines the hypothetical scenario, which is the assumption of EU–Mercosur FTA. Thus, the indicator variable RTA is redefined as $RTA_{ij,t}^{CFL}$, assuming the value of 1 instead for the trade between the two blocs.

The third step solves the model for the hypothetical scenario. The effects of the counterfactual scenario are estimated in a full general equilibrium framework.

As in Baier et al. (2019), the general equilibrium model is solved in changes (instead of levels). According to this approach, data on technology levels, endowments, initial trade frictions, and initial wages are not required to run the model. Changes in trade and welfare, therefore, result from changes in trade frictions.

Given the correspondences $E_j = D_j + w_j L_j$ and $Y_i \equiv w_i L_i = \sum_j X_{ij}$, Equation 3.7 can be rewritten to show the relationship between each country's wages and its ability to reach a market with high levels of demand. Thus, $w_i L_i = \sum_j \frac{A_i w_i^{-\sigma} \tau_{ij}^{-\sigma}}{\sum_k A_k w_k^{-\sigma} t_{kj}^{-\sigma}} \left(D_j + w_j L_j\right)$.

Further, the price level in each country reflects the nation's ability to purchase from exporting countries with high technology and low production cost (i.e., $P_j = \left(\sum_k A_k\, w_k^{-\sigma} t_{kj}^{-\sigma}\right)^{-1/\sigma}$).

Letting the "hat" over a variable denote changes, as in Dekle et al. (2007) (i.e., $\widehat{w}_i$ is the change in the wage levels of country i , w_i'/w_i), the equilibrium in changes can be expressed as

$$Y_i\widehat{w}_i = \widehat{w}_i^{-\sigma} \sum_j \frac{\pi_{ij} e^{\beta RTA_{ij}}}{\widehat{P}_j^{-\sigma}} \left(Y_j\widehat{w}_j + D_j\right), \forall_i, \tag{3.11}$$

where $\widehat{P}_j = \left(\sum_k \pi_{kj} \widehat{w}_k^{-\sigma}\, e^{\beta RTA_{kj}}\right)^{-1/\sigma}$ is the change in price levels for country j and $\pi_{ij} = X_{ij}/E_j$ is the bilateral trade share. Given the change in expenditure $\left(\widehat{E}_i = [Y_i\widehat{w}_i + D_i]/E_i\right)$ and assuming the same world production in the baseline and the counterfactual ($\sum_i Y_i\widehat{w}_i = \sum_i Y_i$), the welfare impact (eq. 3.12) and the trade impact (eq. 3.13) correspond to

$$\widehat{W}_i = \frac{\widehat{E}_i}{\widehat{P}_i}; \tag{3.12}$$

$$\widehat{X}_{ij} = \frac{\widehat{w}_i^{-\sigma} e^{\beta RTA_{ij}}}{\widehat{P}_j^{-\sigma}} \widehat{E}_j. \tag{3.13}$$

To solve the general equilibrium gravity model, we execute the fixed-point algorithm, which iterates until it reaches the equilibrium conditions. Following the algorithm of Head and Mayer (2014) and Baier et al. (2019), we implement our procedure as follows: Before running the iteration loop, the initial condition sets up the change in production cost equal to 1, $\widehat{w}_i = \widehat{P}_i^{-\sigma} = 1$, and the expenditure as $E_i = E_i'$, for any i.

After the initial condition is established, the iteration loops repeat the following four steps until reaching the convergence: (i) update $\widehat{w}_i \; \forall_i$ one time employing $\widehat{w}_i = \left(Y_i^{-1} \sum_j \frac{\pi_{ij} e^{\beta \times RTA_{ij}}}{\hat{P}_j^{-\sigma}} E_j' \right)^{1/1+\sigma}$ for any i; (ii) keep world output fixed by normalizing wages, $\sum_i Y_i \widehat{w}_i = \sum_i Y_i$; (iii) update $\hat{P}_j^{-\sigma} = \sum_k \pi_{kj} \widehat{w}_k^{-\sigma} e^{\beta \times RTA_{kj}}$ for any j; (iv) update $E_j' = Y_j \widehat{w}_j + D_j$ for any j.

The last step consists of reporting indexes of interest, which are the change in trade and welfare.

3.2.3. Data Description

The Food and Agricultural Organization (FAO) of the United Nations provides trade data that group imports (international trade data) and the value of production net of exports (intranational trade data). We use imports rather than exports to build the dependent variable. Because customs administrations more closely monitor the imports due to import duties, the literature uses import data to alleviate the measurement error issue. Intranational trade data can be consistently calculated as the difference between production value and exports (Yotov et al., 2016)

We consider the following commodities/sectors: chicken (1,058)[2], cattle (867), pig (1,035), cotton (767), soybeans (236), wheat (15), and maize (56). Table A-1 (APPENDIX A) describes each sector, showing the equivalent Harmonizing System (HS) and Central Product Classification (CPC) codes. We choose these sectors because

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[2] FAO item code.

they meet the criteria for forming a database with both intra- and international data. Regional trade agreement data are from the United States International Trade Commission (USITC, 2018). The panel data framework includes the years 1997, 2000, 2003, 2006, 2009, 2012, and 2015. The analysis includes all signatories of the EU–Mercosur FTA as well as countries with more than $300 million in trade (summed over the entire period for all commodities), for a total of 58 nations.

3.3. Results

The present study was designed to determine the effects of an EU–Mercosur FTA on agricultural markets. First, we show that the RTA estimates for the selected commodities are generally in line with the literature. Second, we comment on the significant increase in exports from Mercosur countries to the EU. Finally, we contrast the overall export growth with welfare gains, highlighting the mismatch between them.

The analysis starts with a PPML estimation of the gravity model (equation 3.10) with a 3-year panel interval. Table 3-1 reports the results obtained from the regression of trade flow over the Regional Trade Agreement (RTA), outward multilateral resistance (exporter fixed effects), inward multilateral resistance (importer fixed effects), and the symmetric pair fixed effects. The coefficients of the RTA represent how much the trade between the two countries would increase, on average, if both signed an RTA—holding the endogenous variables of the model fixed.

Table 3-1 PPML Estimation of Regional Trade Agreement Effect on Trade for Selected Commodities, 1997 – 2015

	Cattle	Chicken	Cotton	Maize	Pig	Soybean	Wheat
RTA	0.725*	1.484***	0.306*	0.195	0.616**	-0.530*	0.350**
	(0.403)	(0.343)	(0.175)	(0.235)	(0.293)	(0.300)	(0.149)
Exporter FE	Y	Y	Y	Y	Y	Y	Y
Importer FE	Y	Y	Y	Y	Y	Y	Y
Pair FE	Y	Y	Y	Y	Y	Y	Y

Notes: PPML – Pseudo Poisson Maximum Likelihood; Y - yes. Standard errors in parentheses. ***p<0.01, **p<0.05, *p<0.1

A change in the RTA indicator variable triggers an effect on trade volume calculated in percentage as $\left[\left(e^{\hat{\beta}_{RTA}}-1\right)\times 100\right]$. The literature uses Bergstrand and Baier (2007) RTA estimate as a benchmark: The RTAs signed between 1960 and 2000, on average, increased the trade by 114% $[(e^{0.76}-1)\times 100]$. Although we did not include tariffs due to the lack of consistency in data, our model does not preclude the estimation of equivalent tariff effects, because of the structural interpretation tariffs coefficient as trade elasticity of substitution ($\beta_{TARIFF}=-\sigma$). From the structural gravity model and drawing σ from the literature, Yotov et al. (2016) demonstrated that the equivalent tariff effect of RTAs could be obtained from $\left[\left(e^{\hat{\beta}_{RTA}/-\hat{\sigma}}-1\right)\times 100\right]$.

The import and export fixed effects absorb unilateral and nondiscriminatory trade policies such as export subsidies or most-favored-nation (MFN) tariffs (Head & Mayer, 2014). Given that nondiscriminatory policies are likely to be heterogeneous across sectors, it is desirable to evaluate FTA effects on a specific sector (i.e., commodities). Despite the fact that import/export fixed effects account for multilateral resistance, they control all country-level idiosyncratic factors such as size, income level, agricultural comparative advantages, and demand structure (Arita et al., 2017). Pair fixed effects capture bilateral, time-invariant covariates measuring trade costs better than the standard gravity variables (distance, common language, colony, shared border) (Egger and Nigai (2015) and Agnosteva et al. (2019)).

Our results indicate that trade liberalization has a more significant positive impact on the meat sectors than on the grain sectors. According to Table 3-1, an RTA increases the trade flow of cattle, on average, by 106.5% [(exp(0.73)-1)*100], an amount similar to those proposed by Arita et al. (2017), 101.4%, and Del Fiori (2015), 82%. For chicken, the RTA raises trade by 341.1%, in accordance with Arita et al., 469.7%, but in contrast to Del Fiori, -22%. An RTA entails an 85.2% increase in pork commercialization after an agreement; however, Arita et al. found an effect of 6.2%, and Del Fiori found -32.3%. A note of caution is due here since the cattle sector is not statistically significant at the 5% level[3].

RTA has mixed effects on grains. The results exhibit an increase of 41.9% in wheat trade as a result of RTA, while previous literature shows a decrease of 12.2% (Arita et al., 2017). For corn, Table 3-1 reveals a trade expansion of 21.5% for maize commerce coming from RTA, along the same lines as Arita et al. (109.6%). One unanticipated finding was the negative elasticity for Soybean (-41.1%). This outcome needs to be interpreted with caution because of the level of significance, as shown in Table 3-1. However, the growing Chinese demand for soybeans in a context with only

[3] For Arita et al. (2017), only poultry and corn were statistically significant at the 5% level. Pork was not statistically significant for Del Fiori (2015).

two major suppliers (Brazil and the USA) may have weakened the effect of FTA for this commodity in the period under investigation.

Given the elasticities in Table 3-1, we turn our attention to how an EU–Mercosur FTA would change exports to the EU. Table A-2 (APPENDIX A) details our findings, which suggest a considerable increase in meat (chicken, cattle, and pig) exports from Mercosur to the EU. Argentina and Brazil would increase chicken and cattle exports to the EU by more than 45%. Interestingly, Japan, Russia, Austria, and the United States would substantially shrink their chicken exports by more than 45%. The market gain of Latin American countries entails a reduction in European countries' exports to their continental peers. Argentina and Brazil also nearly double their pig exports to the EU.

Mercosur's countries boost their grain exports to the EU in the case of an FTA between both blocs. Cotton and wheat exhibit roughly 30% growth in exports from Argentina and Brazil to the European market. All four Mercosur countries would increase their maize exports by no more than 6%, but countries such as the United States and Canada could suffer up to 14% losses in the European market. Soybean presents anomalous behavior because of the adverse effects of an RTA. Figure 3-1 summarizes the finding for selected countries.

Mercosur countries improve their welfare by increasing total exports to a considerable number of countries. Tables A-3 and A-4 (APPENDIX A) detail the results. Figure 3-2 compiles the EU–Mercosur RTA implications to trade and welfare. Total maize export growth in Argentina (0.8%), Brazil (1.5%), and Paraguay (1.1%) is more pronounced than in the United States (0.2%). While Argentina (9.8%) and

Paraguay (11.4%) capture the best welfare gains from maize, Brazil hardly increases corn welfare. Argentina, Paraguay, and Uruguay also exhibit the highest wheat welfare gain, and, along with Brazil, have the most substantial growth in overall wheat exports. Interestingly, the United States displays the most welfare gain from (2.6%), whereas no country experiences growth in its total cotton export of more than 1%. Soybean results hurt Mercosur countries' exports and welfare gains.

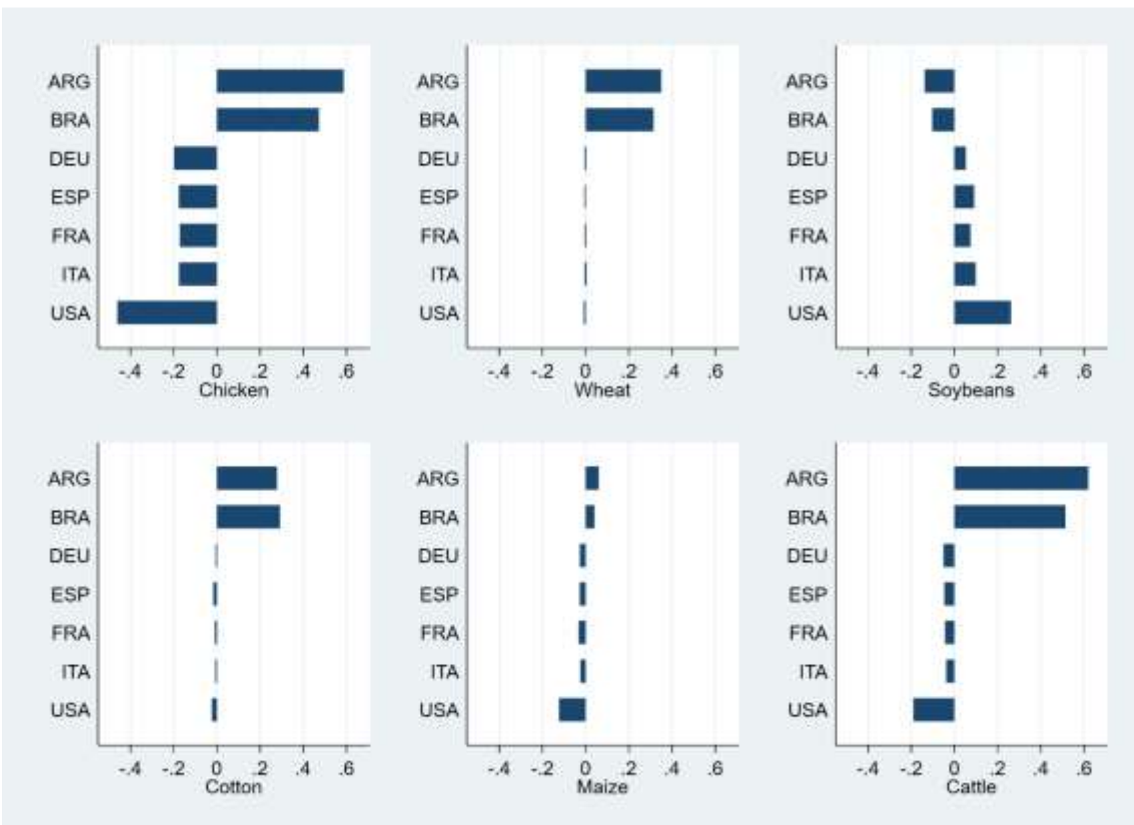

Figure 3-1 EU – Mercosur RTA Effects on Exports to EU for Selected Countries

Chicken has the most significant variation in both welfare and trade gains. Despite Luxembourg (-13.3%), Malta (-13.57%), and Ireland (-13.4%) reducing their total exports, these countries present the highest welfare gains: 15%, 13.8%, and 8.8%, respectively. In contrast, Uruguay (17.5%), Brazil (10.7%), and Argentina (10.2%) lead growth in chicken exports with small welfare gains of 0.01%, 2.7%, and 0.9%, respectively. The meat sector presents similar results. The highest welfare gains go to European countries, while Latin American countries record the most significant increases in exports. The RTA does not generate substantial variations in the economic welfare of the pig sector.

One unanticipated finding was that some countries included in the EU–Mercosur agreement experience welfare losses as Figure 3-2 shows, including France with maize (-3.9%), Brazil with wheat (-0.9%), Uruguay with soybeans (-46.2%), Spain with cotton (-0.76%), Austria with cattle (-1.4%), and Belgium with chicken (-18.6%).

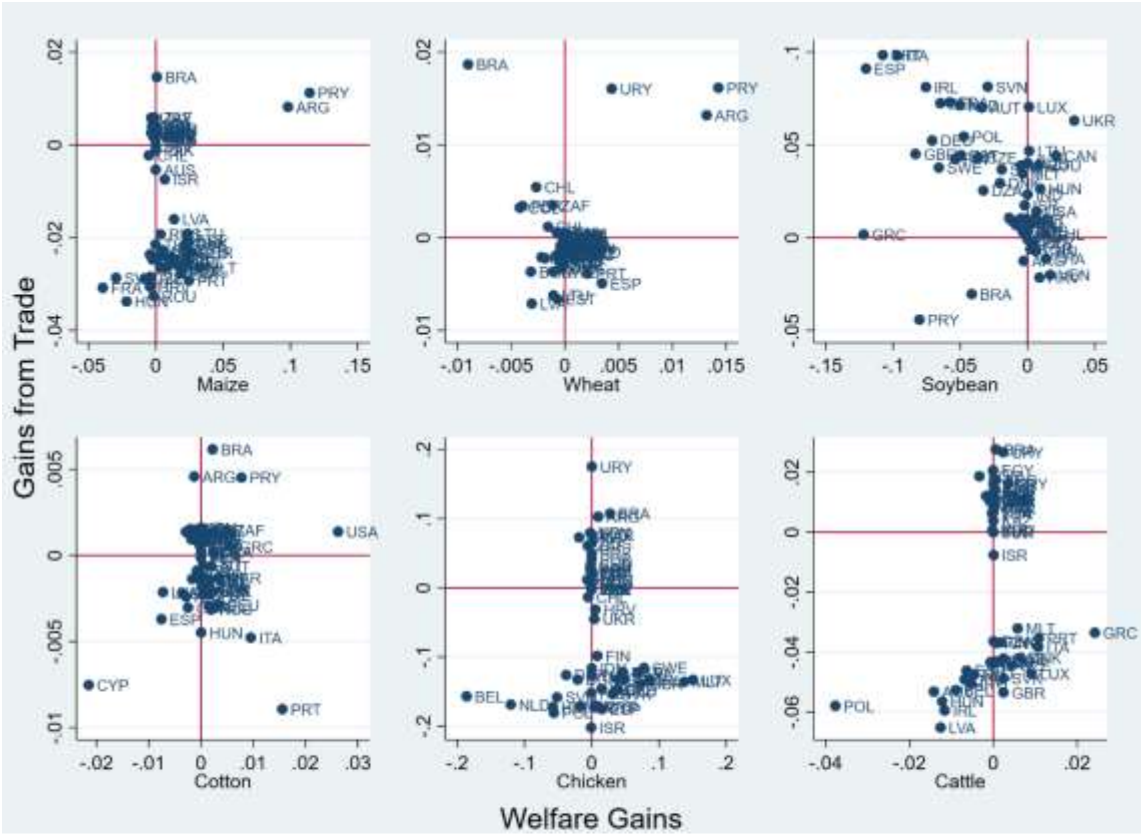

Figure 3-2 EU – Mercosur RTA Effects on Trade and Welfare Gains

Our findings are consistent with those of Baier et al. (2019), who observed not only small welfare gains (average 0.14%) but also welfare gains that are smaller relative to trade gains (the "average" scenario of FTA between the EU and the US). However, our outcomes are contrary to Costinot and Rodriguez-Clare (2014), who found an 8.3% increase in welfare by investigating the move from autarky to liberalization under a scenario with perfect competition, multiple sectors, and intermediates, and Anderson et al. (2018), who observed a 5.2% increase in welfare by examining the complete removal of international borders to trade in manufactures.

The literature presents two possible explanations for welfare gains being relatively smaller than trade gains. Ossa (2015) demonstrated that RTAs have a larger effect on trade than on welfare because the implicit cost of welfare to replace one's own supply is lower. Head and Mayer (2014) also pointed out how strong trade impacts may have small welfare consequences. Like Baier et al. (2019), our model omits factors that deliver more substantial gains from trade such as multiple industries, trade intermediaries, and dynamic effects. Future investigations may include these factors in the model.

The findings support the hypothesis that EU tariff barriers cause trade distortions of Mercosur agricultural exports given Latin American countries' growth in exports and welfare gains. Overall, the FTA generates gains to both Mercosur and the EU due to the increase in welfare and trade of agricultural products.

3.4. Conclusion

This study set out to assess the impact to agricultural products (chicken, cattle, pig, cotton, soybean, wheat, and maize) of an EU–Mercosur FTA. The results show Mercosur countries (Argentina, Brazil, Paraguay, and Uruguay) increasing their agricultural exports, especially to Europe, but with relatively small welfare gains. On the other hand, the European countries may reduce their exports to their fellow countries, but with larger welfare gains, especially in the meat sector.

This research has shed light on the contentious issue of agricultural trade. We add to a growing body of research that indicates the gravity model as the most appropriate approach to investigating trade policy. This study is one of the first attempts to examine agricultural trade under a gravity model framework, including pair fixed effects and intranational trade. This research is the only empirical investigation to date into the impact of an EU–Mercosur FTA on agricultural products. The insights gained from this study may be of assistance to the policy makers who will ratify the FTA.

The current research has considered the context of only one sector and only labor as a production factor. Further research might include land and capital. It would be interesting to assess a scenario with all FTAs that are currently being negotiated. More research is required to account for multiple sectors and intermediaries, exploring the linkages among them. Future studies should attempt to identify the effects of FTA under a dynamic equilibrium framework.

3.5. References

Agnosteva, D. E., Anderson, J. E., & Yotov, Y. V. (2019). Intra-National Trade Costs: Assaying Regional Frictions. *European Economic Review, 112*, 32-50. doi:10.1016/j.euroecorev.2018.11.008

Aichele, R., Felbermayr, G. J., & Heiland, I. (2016). TTIP and Intra-European Trade: Boon or Bane? *Journal of Economics and Statistics, 6*(236), 639-664.

Allen, T., Arkolakis, C., & Takahashi, Y. (2020). Universal Gravity. *Journal of Political Economy*. 2(218), 393-433

Anderson , J. E. (1979). A Theoretical Foundation for the Gravity Equation. *The American Economic Review, 69*(1), 106-116.

Anderson , J. E. (2011). The Gravity Model. In K. J. Arrow & T. F. Bresnahan (Eds.), *Annual Review of Economics, Vol 3* (Vol. 3, pp. 133-160).

Anderson, J. E., Borchert, I., Mattoo, A., & Yotov, Y. V. (2018). Dark Costs, Missing Data: Shedding some Light on Services Trade. *European Economic Review, 105*, 193-214. doi:10.1016/j.euroecorev.2018.03.015

Anderson , J. E., Larch, M., & Yotov, Y. V. (2018). GEPPML: General equilibrium Analysis with PPML. *World Economy, 41*(10), 2750-2782. doi:10.1111/twec.12664

Anderson, J. E., & van Wincoop, E. (2003). Gravity with Gravitas: A Solution to the Border Puzzle. *American Economic Review, 93*(1), 170-192. doi:10.1257/000282803321455214

Anderson , J. E., Vesselovsky, M., & Yotov, Y. V. (2016). Gravity with Scale Effects. *Journal of International Economics, 100*, 174-193. doi:10.1016/j.jinteco.2016.03.003

Anderson, J. E., & Yotov, Y. V. (2010). The Changing Incidence of Geography. *American Economic Review, 100*(5), 2157-2186. doi:10.1257/aer.100.5.2157

Arita, S., Beckman, J., & Mitchell, L. (2017). Reducing Transatlantic Barriers on US-EU Agri-Food Trade: What are the Possible Gains? *Food Policy, 68*, 233-247. doi:10.1016/j.foodpol.2016.12.006

Arkolakis, C., Costinot, A., & Rodriguez-Clare, A. (2012). New Trade Models, Same Old Gains? *American Economic Review, 102*(1), 94-130. doi:10.1257/aer.102.1.94

Armington, P. S. (1969). Theory of Demand for Products Distinghished by Place of Production. *International Monetary Fund Staff Papers, 16*(1), 159-178.

Arvis, J. F., & Shepherd, B. (2013). The Poisson Quasi-Maximum Likelihood Estimator: a Solution to the 'Adding Up' Problem in Gravity Models. *Applied Economics Letters, 20*(6), 515-519. doi:10.1080/13504851.2012.718052

Baier, S. L., Yotov, Y. V., & Zylkin, T. (2019). On the Widely Differing Effects of Free Trade Agreements: Lessons from Twenty Years of Trade Integration. *Journal of International Economics, 116*, 206-226. doi:10.1016/j.jinteco.2018.11.002

Bergstrand, J. H., & Baier, S. L. (2007). Do Free Trade Agreements Actually Increase Members' International Trade? *Journal of International Economics, 71*(1), 72-95. doi:10.1016/j.jinteco.2006.02.005

Bergstrand, J. H., Larch, M., & Yotov, Y. V. (2015). Economic Integration Agreements, Border Effects, and Distance Elasticities in the Gravity Equation. *European Economic Review, 78*, 307-327. doi:10.1016/j.euroecorev.2015.06.003

Calil, Y. C. D., & Ribera, L. (2019). Brazil’s Agricultural Production and Its Potential as Global Food Supplier. *Choices, 34*, 1-12.

Chaney, T. (2008). Distorted Gravity: The Intensive and Extensive Margins of International Trade. *American Economic Review*, *98*(4), 1707-1721. doi:10.1257/aer.98.4.1707

CHRTD. (2019). Resourcetrade.earth. from Chatham House Resource Trade Database. Retrived from http://resourcetrade.earth/ [Accessed June 19, 2019].

Costinot, A., & Donaldson, D. (2012). Ricardo's Theory of Comparative Advantage: Old Idea, New Evidence. *American Economic Review*, *102*(3), 453-458. doi:10.1257/aer.102.3.453

Costinot, A., & Donaldson, D. (2016). *How Large Are the Gains from Economic Integration? Theory and Evidence from U.S. Agriculture, 1880-1997*. Working Paper.

Costinot, A., & Rodriguez-Clare, A. (2014). Trade Theory with Numbers: Quantifying the Consequences of Globalization. In G. Gopinath, E. Helpman, & K. Rogoff (Eds.), *Handbook of International Economics, Vol 4* (pp. 197-261).

Dai, M., Yotov, Y. V., & Zylkin, T. (2014). On the Trade-Diversion Effects of Free Trade Agreements. *Economics Letters, 122*(2), 321-325. doi:10.1016/j.econlet.2013.12.024

Deardoff, A. (1998). Determinants of Bilateral Trade: Does Gravity Work in a Noclassical World? In J. A. Frankel (Ed.), *The Regionalization of the World Economy*. Chicago: University of Chicago Press.

Dekle, R., Eaton, J., & Kortum, S. (2007). Unbalanced Trade. *American Economic Review, 97*(2), 351-355. doi:10.1257/aer.97.2.351

Del Fiori, D. (2015). *Uma Avaliação de Efeitos Potenciais de Acordos Regionais entre Brasil e União Européia para as Exportações de Produtos Agrícolas Brasileiros.* [Doctoral Dissertation], Universidade de São Paulo, Piracicaba. Retrieved from http://www.teses.usp.br/teses/disponiveis/11/11132/tde-03022016-162255/publico/Diogo_Del_Fiori_versao_revisada.pdf [Accessed June 17, 2019].

Donaldson, D. (2018). Railroads of the Raj: Estimating the Impact of Transportation Infrastructure. *American Economic Review, 108*(4-5), 899-934. doi:10.1257/aer.20101199

Durand-Morat, A. (2019). Agricultural Production Potential in Southern Cone: Argentina, Paraguay and Uruguay. *Choices, 34*(3).

Eaton, J., & Kortum, S. (2002). Technology, Geography, and Trade. *Econometrica, 70*(5), 1741-1779. doi:10.1111/1468-0262.00352

Egger, P., & Nigai, S. (2015). Energy Demand and Trade in General Equilibrium. *Environmental & Resource Economics, 60*(2), 191-213. doi:10.1007/s10640-014-9764-1

Fally, T. (2015). Structural Gravity and Fixed Effects. *Journal of International Economics*, *97*(1), 76-85. doi:10.1016/j.jinteco.2015.05.005

FAO. (2019). FAOSTAT Crops and Livestock Products. Retrieved from http://www.fao.org/faostat/en/#data/TP [Accessed May 22, 2019].

Ghazalian, P. L. (2017). The Effects of NAFTA/CUSFTA on Agricultural Trade Flows: An Empirical Investigation. *Canadian Journal of Agricultural Economics-Revue Canadienne D Agroeconomie, 65*(2), 219-248. doi:10.1111/cjag.12119

Grossman, G. M. (2016). The Purpose of Trade Agreements. In K. Bagwell & R. W. Staiger (Eds.), *Handbook of Commercial Policy, Vol 1a* (pp. 379-434). New York: North Holland.

Head, K., & Mayer, T. (2014). Gravity Equations: Workhorse, Toolkit, and Cookbook. In G. Gopinath, E. Helpman, & K. Rogoff (Eds.), *Handbook of International Economics, Vol 4* (pp. 131-195).

Heerman, K. E. R., Arita, S., & Gopinath, M. (2015). Asia-Pacific Integration with China Versus the United States: Examining Trade Patterns under Heterogeneous Agricultural Sectors. *American Journal of Agricultural Economics, 97*(5), 1324-1344. doi:10.1093/ajae/aav038

Heid, B., & Larch, M. (2016). Gravity with Unemployment. *Journal of International Economics, 101*, 70-85. doi:10.1016/j.jinteco.2016.03.008

Heid, B., Larch, M., & Yotov, Y. V. (2017). "Estimating the Effects of Non-discriminatory Trade Policies within Structural Gravity Models,". CESIFO Working Paper. Retrived from https://www.cesifo.org/en/publikationen/2017/working-paper/estimating-effects-non-discriminatory-trade-policies-within [Accessed May 18, 2019].

Josling, T., Paggi, M., Wainio, J., & Yamazaki, F. (2015). Latin American Agriculture in a World of Trade Agreements. *American Journal of Agricultural Economics, 97*(2), 546-567. doi:10.1093/ajae/aau116

Larch, M., & Wanner, J. (2017). Carbon tariffs: An Analysis of the Trade, Welfare, and Emission Effects. *Journal of International Economics, 109*, 195-213. doi:10.1016/j.jinteco.2017.09.003

Larch, M., & Yotov, Y. V. (2016). *General equilibrium trade policy analysis with structural gravity*. WTO Staff Working Paper, No. ERSD-2016-08. Geneva. Retrieved from http://hdl.handle.net/10419/144543 [Accessed July 03, 2019].

Martin, W. (2018). A Research Agenda for International Agricultural Trade. *Applied Economic Perspectives and Policy, 40*(1), 155-173. doi:10.1093/aepp/ppx063

Olivero, M. P., & Yotov, Y. V. (2012). Dynamic Gravity: Endogenous Country Size and Asset Accumulation. *Canadian Journal of Economics-Revue Canadienne D Economique, 45*(1), 64-92. doi:10.1111/j.1540-5982.2011.01687.x

Ossa, R. (2015). Why Trade Matters After All. *Journal of International Economics, 97*(2), 266-277. doi:10.1016/j.jinteco.2015.07.002

Silva, J. M. C. S., & Tenreyro, S. (2006). The Log of Gravity. *Review of Economics and Statistics, 88*(4), 641-658. doi:10.1162/rest.88.4.641

Tombe, T. (2015). The Missing Food Problem: Trade, Agriculture, and International Productivity Differences. *American Economic Journal-Macroeconomics, 7*(3), 226-258. doi:10.1257/mac.20130108

Trebilcock, M., & Pue, K. (2015). The Puzzle of Agricultural Exceptionalism in International Trade Policy. *Journal of International Economic Law, 18*(2), 233-260. doi:10.1093/jiel/jgv022

USITC. (2018). The Dynamic Gravity Dataset: 1948-2016. Retrieved from https://www.usitc.gov/data/gravity/dataset.htm [Accessed July 19, 2019].

World Bank. (2019). Tariff Rate, Applied, Simple Mean, Primary Products (%). https://data.worldbank.org/[Accessed July 19, 2019].

Yotov, Y. V. (2012). A Simple Solution to the Distance Puzzle in International Trade. *Economics Letters, 117*(3), 794-798. doi:10.1016/j.econlet.2012.08.032

Yotov, Y. V., Piermartini, R., Monteiro, J.-A., & Larch, M. (2016). *An Advanced Guide to Trade Policy Analysis: The Structural Gravity Model*. Geneva: World Trade Organization.

4. ECONOMIC FEASIBILITY OF CROP-LIVESTOCK INTEGRATION SYSTEM IN BRAZIL

4.1. Introduction

The forecasted global population increase of 3 billion additional people by 2050 and increasing per capita food consumption create pressure for more agricultural production (FAO, 2012). To meet the growing demand for food with a sustainable supply system, Brazil has been fostering the Crop – Livestock Integration System (CLIS).

Unlike the northern hemisphere countries that produce only one crop per year, the CLIS allows the tropical country to harvest three cultures (i.e., soybean, corn, and livestock) during the year in the same land in a sustainable way (Nicodemo & Primavesi, 2019). Of the three pillars of sustainability[4], CLIS has been studied under environmental and human dimensions (Garrett et al., 2017). However, still a paucity of study on the economically viable pillar.

The purpose of this paper is to examine the economic feasibility of the CLIS relative to the economic viability of the traditional soybean and corn production in Brazil. So, we develop a stochastic net present value (NPV) model with a unique database from the Brazilian Agricultural Research Corporation (Embrapa).

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[4] Purvis et al. (2019) discusses the three pillars of sustainability.

The economic viability brings economic incentives to the Brazilian farmers to increase agricultural production in the same area without increasing deforestation. So, the boosting demand for food may be attended in a context that sustainable agricultural production needs to grow 70% by 2050 to feed the world FAO (2019).

The CLIS has policy implications as well, given that Brazil is a signatory of the Paris Climate Agreement (United Nations, 2019). In the agreement, one of the country's proposed strategies to reduce greenhouse gas emission was the encouragement of CLIS. In 2013, the Brazilian Congress passed a law[5] establishing the national policy for CLIS. One of the law's clauses created a subsidized credit line for producers who adopt CLIS. Nowadays, the interest rate to finance CLIS is one of the cheapest available to Brazilian farmers (MAPA, 2019).

The CLIS is relevant for Brazilian agriculture and, therefore, for the world agricultural markets. In 2017, the agricultural census recorded about 14 million hectares under the integrated production system, while total hectares for crop production summed 63 million hectares (IBGE, 2018). The CLIS technique has been steadily spreading in the country since 2005, when the occupied area was 1.87 million ha, that is, a roughly 700% growth from 2005 to 2017 (Embrapa, 2019). Calil and Ribera (2019) discussed the role of Brazil as a global food supplier highlighting the countries' ability to increase productivity and be one of the world leaders in the production and export of products such as soybean, corn, and meat.

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[5] Law 12805/2013 http://www.planalto.gov.br/ccivil_03/_Ato2011-2014/2013/Lei/L12805.htm

The next section discusses the specifics of the CLIS. The methods section shows how we construct four different scenarios to evaluate and contrast the economic feasibility of the CLIS. We incorporate risk by simulating the net present value for each one of the scenarios, then, cumulative density function, first-order stochastic dominance, second-order stochastic dominance, stochastic dominance with respect to a function, and stochastic efficiency with respect to a function to rank the scenarios. So, in the results section, we show how CLIS outperforms traditional farming discussing the implications. Finally, the last section is summary and conclusions.

4.2. The Brazilian Crop-Livestock Integration System

This section illustrates the Brazilian CLIS. The technique is described highlighting the importance of brachiaria grass. Finally, the benefits of the system are listed.

The Brazilian integrated system evolved from Embrapa technology to recover pasture. Dias-Filho (2014) estimates 100 million hectares of degraded pasture in Brazil with data from the 2006 Agricultural Census. For more than forty years, the country has been investigating solutions for soil degradation, for instance, Seguy et al. (1984). In the nineties, an Embrapa technology, Sistema Barreirao (Great Barrier System), provided a promising solution. By combining crops (rainfed rice, corn, and sorghum) with fodder (Brachiaria and Andropogon), the Sistem Barreirao recovered pastures (Kluthcouski et al. (1991) and (de Oliveira et al., 1996)). Sistema Barreirao is the precursor of the Brazilian integrated system.

Balbino, Barcellos, et al. (2011) defined the integrated system as a sustainable agricultural production strategy in which three different cultures – agricultural, livestock, and forest – are combined within the same area to yield synergistic interactions between the components of agroecosystem highlighting the environmental adequacy, labor valorization, and economic viability. The technology can be implemented using mixed, rotation, or succession crops.

The integration has four possible configurations: crop-livestock (agro-pasture system), crop-livestock – forest, livestock – forest (silvopasture system), and crop – forest (agroforest system) (Balbino et al., 2019). Among these arrangements, the crop-livestock strategy is the most common occurring in 83% of the area used in Brazil for the integration system in 2015 (Embrapa, 2019). Since the crop-livestock is the predominant strategy adopted in Brazil, our study focuses on agro-pasture system.

The CLIS soybean, corn, grass, and cattle. Calil and Ribera (2019) explained the dynamics of the process on a farm as follows: after soybeans are harvested, farmers plant corn mixed with grass (brachiaria). When the corn is harvested, the grass is ready for grazing. The cattle are fattened in the pasture. After the cattle are removed for slaughter, the area is dried out, and soybeans are planted on the straw using no-till practices. The system occurs within one crop year without irrigation. Table 4-1 illustrates the time frame of the system that occurs during one crop year without irrigation.

Table 4-1 The Crop-Livestock Integration System Timeframe

	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.
Soybean	x	x	x	x	x							
Corn					x	x	x	x	x			
Grass					x	x	x	x	x	x	x	x
Cattle									x	x	x	x
Temp. [a] (°F)	75.9	75	73.9	75.6	75.7	74.7	71.6	68.7	68.4	71.6	75.4	76.8
PCPN[b] (mm)	146	190	246	240	194	190	111	27	6	5	15	44

Note: a –average temperature in Goias, b – average precipitation Goias. Data for "a" and "b" are adapted from Climate-Data (2019)

Brachiaria plays a crucial role in CLIS. The grass regenerates the soil for crop production and provides feed for the livestock during the dry season. Because the roots reach more than seventy inches deep, brachiaria improves soil compaction (loosening the soil) and soil absorption (forming pores for water inlet) (Brighenti et al., 2019; Paciullo & Gomide, 2019). Brachiaria with corn leftovers (highly protein straws) propitiates pasture during the arid months of the year (Table 4-1). Therefore, it incorporates organic matter in the soil to increase soybean yield.

Kichel and Miranda (2001) and Balbino et al. (2019) enumerates some of the main advantages of using CLIS: optimization and intensification of soil nutrient cycling, improvement of the quality and conservation of the soil's productive characteristics, greater efficiency in the use of resources (water, light, nutrients, and capital), reduction of labor seasonality, biodiversity conservation, mitigation of greenhouse gas, sustainable agriculture, creation of direct and indirect jobs, applicable to farms of all sizes and profiles.

CLIS is spread all over the world. Commercial-scale of integrated systems are also present in Australia (Bell & Moore, 2012), France (Veysset et al., 2014), New

Zealand (Niles et al., 2017), and the United States (Sulc & Franzluebbers, 2014). Australia usually integrates wheat, canola, and brassicas with sheep or chickpea and cereal with beef cattle. France commonly combines beef cattle with cereals, rapeseed, and sunflower. New Zealand generally associates wheat, brassicas, kale, fodder beet, oats, barley, peas, beans, turnips, and rapeseed with beef cattle, dairy cattle, or sheep.

Although CLIS is not widely practiced in the U.S., Sulc and Franzluebbers (2014) foresee farmers adopting sod-based crop rotations and grazed cover crops. The authors listed some reasons for the producers' lack of interest in CLIS: the convenience of commodity support policies, ease of managing a single crop, and rising market prices for their products. At the same time, cattle ranchers show more interest in integrating cash crops with livestock operations, given the rise in input costs.

4.3. Methods

This section develops the stochastic net present value (NPV) model to evaluate the economic feasibility of the CLIS. Then, we present the approach to rank the different scenarios. In our farm model, the producer rents the land to produce in four different scenarios.

We use Embrapa's data to estimate and calibrate the farm model. Yields and costs of production are based on Conab (2019) and an Embrapa Technological Reference Unit[6], Fazenda Santa Brígida, located in the state of Goiás. Crops and

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[6] Technological Reference Unit is a physical model of production systems, implemented in a public or private area, aiming at the validation, demonstration and transfer of technologies generated, adapted and / or recommended by the National Agricultural Research System (SNPA) for the region (Balbino, Porfirio, et al., 2011).

Livestock prices are from the Agrolink database. Farm risks are explicitly included in the model through the use of probability distribution to simulate random yields and price values. Mean annual forecasted prices and yield comes from trend regression projections.

In the first scenario, soybean is produced on 1500 hectares (ha). In the second scenario, the farmer plant soybeans on 1500 ha and corn at 1200 ha. In the third scenario, besides farmer soybean on 1500 ha, the producer implements the crop-livestock integration technique on 600 ha yielding corn and cattle. In the last scenario, crop-livestock yields cattle and corn at 1000 ha after soybean was produced in 1500 ha. The first two scenarios are named traditional farming, while the last two scenarios are caller crop-livestock integration scenarios.

The integration scenarios do not cover the total area (1500 ha) because planting and harvesting take place gradually, as there is an optimal sequence that takes into account the machinery and the climatic conditions. The scenarios were built from conversations with Embrapa technicians and visits to CLIS farms.

The stochastic NPV methodology is one of the main approaches to investigate the viability of risky projects (i.e., Zapata et al. (2017), Maisashvili et al. (2016), Rezende and Richardson (2015), Monge et al. (2014), Outlaw et al. (2007), Richardson et al. (2007)). We follow Richardson (2008) top-down approach, which enumerates seven steps to build a simulation model.

Richardson's seven methodological steps are: (1) determine the model's use; (2) define the key output variables; (3) establish the intermediate output; (4) write the equations; (5) chooses the inputs and calculate the variables; (6) identify the stochastic variables; and, (7) validation and documentation of the model.

The purpose of the model is to the feasibility of the crop-livestock integration system, collaborating in the decision making of farmers and policymakers. The key output variable (KOV) is the net present value (NPV) because NPV captures if the project is worth more than it costs. Also, NPV is preferable to other project appraisal measures such as internal rate of return (IRR), book rate of return, and payback period, as Brealey et al. (2019) show. Besides, Graham and Harvey (2002) highlight NPV as one of the most popular procedures in capital budgeting.

Since we choose NPV as KOV, the necessary variables to estimate the NPV corresponds to the intermediate output variables. So, we calculate the income statement, balance sheet, and cash flow for the farm model. The fourth step writes down the equations underpinning the financial statements and KOV. Hence, the NPV can be written as:

$$NPV = \sum_{t=0}^{T} \frac{(Cash\ Inflow - Cash\ Outflow)_t}{(1+r)^t}. \qquad (4.1)$$

The NPV is the sum of discounted cash flow. To discount the cash flow, we calculate the cost of capital $r = 7.54\%$. We used the weighted average cost of capital method assuming SELIC[7] as the risk-free rate, Ibovespa[8] as the market return, ABC Plan[9] interest rate, and Damodaram's[10] Farming/Agricultural beta. The structure of capital corresponds to 40% debt and 60% equity.

The cash flow forecast period comprehend ten years, $(T = 10)$. Pro-forma financial statements such as income statement, cash flow statement, and balance sheet are computed for the standard Brazilian farm. Most of the accounting identities define the relationships of the variables in a firm-level model. Cash inflow and cash outflow are a result of these relationships and can be presented as:

$$Cash\ Inflows_t = Beginning\ Cash_t + NCFI_t + Interest\ Earned_t \text{ and} \tag{4.2}$$

$$Cash\ Outflows_t = Pricicpal\ Payments_t + Family\ Living_t + Income\ Tax_t. \tag{4.3}$$

Among the financial statements, the particular interest for us is the net cash farm income $(NCFI)$, defined as the difference between total receipts $(Receipts_t)$ and total expenses $(Expenses_t)$.

$$Receipts_t = P_c Q_c + P_c Q_{ci} + P_s Q_s + P_s Q_{si} + P_{ca} Q_{ca} \tag{4.4}$$

[7] The Special System for Settlement and Custody (Selic) is the common risk-free rate used in Brazil (https://www.bcb.gov.br/en/financialstability/selicsystem)

[8] The Ibovespa index is the main market return indicator in Brazil. It combines stock companies listed in Brazil accounting for about 80% of Brazilian capital market financial volume (http://www.b3.com.br/en_us/market-data-and-indices/indices/broad-indices/ibovespa.htm).

[9] Brazilian’s farmers can finance their agricultural sustainable activities with ABC Plan credit line (http://www.agricultura.gov.br/assuntos/sustentabilidade/plano-abc/financiamento).

[10] Source: http://pages.stern.nyu.edu/~adamodar/New_Home_Page/datafile/Betas.html

Receipts at time t add the price (P) of each commodity at Goias state times the quantity (Q) produced of each good. The quantity produced is the product of yield and area. The subscripts represent the following agricultural products: corn (c), corn integrated (ci), soybean (s), soybean integrated (si), and cattle (ca). The expenses at time t sums the total variable costs (VC) and the fixed costs (FC).

$$Expenses_t = FC_t + VC_c Q_c + VC_{ci} Q_{ci} + VC_s Q_s + VC_{si} Q_{si} + VC_{ca} Q_{ca}, \tag{4.5}$$

The next step consists in determining the inputs (exogenous) and calculate the variables (endogenous). Examples of exogenous variables include annual interest rate, rates of inflation, initial endowment, variable costs, and fixed costs. Production, costs, prices, quantity demanded, and net returns are examples of endogenous variables.

In the sixth step, we identify the stochastic variables prices (corn, soybean, cattle) and yields (corn, corn integrated, soybean, soybean integrated, and cattle). The random variable quantity produced (Q) for each good (g) at time t can be expressed as:

$$Q_{gt=hectares_{gt} \times yield_{gt}}, \tag{4.6}$$

The goods (g) correspond to the agricultural products (corn (c), corn integrated (ci), soybean (s), soybean integrated (si), and cattle (ca)) while the hectares vary according to the scenarios. Based on ten years of forecasted means (2019 – 2028) and ten years of actual historical yield and price data for all goods (2009 – 2018), a multivariate empirical distribution $(MVEMP)$ with deviates from trend function was estimated for yields and prices. Noting the non-parametric feature of $MVEMP$, Maisashvili et al. (2016) comment that this distribution absorbs the inter-temporal (across time) and intra-temporal (across variable) correlation among the random variables as explained. Because of the correlation among the goods and their prices, few historical observations to estimate the true parameters, finite range of possible values, we employed the $MVEMP$ proposed by Richardson et al. (2000).

The last step is the validation and documentation of the model. To validate the yield and price stochastic component, we apply the Student's t-test to evaluate the historical correlation matrix against the correlate matrix from the simulated data. Also, we conducted meetings with crop-livestock's experts from Embrapa for output review.

The simulation model output a unique distribution of NPV for each risky scenario. To evaluate the alternative strategies, we rank the four scenarios under cumulative density function, first-order stochastic dominance, second-order stochastic dominance, stochastic dominance with respect to a function, and stochastic efficiency with respect to a function.

The cumulative distribution function (CDF) graphs the probability associated with each level of NPV. CDFs lying to right are preferred because, for a certain probability level, the higher NPV will be further to the right. However, when CDF line crosses, the ranking classification is ambiguous. To circumvent this problem, the ranking system can be based on a utility function. We assume the farmer desires to maximize his negative exponential utility function whose parameters are wealth (W) and absolute risk aversion coefficient (r_a): $U(W) = 1 - \exp(-r_a W)$.

Hardar and Russel (1969) presented the First and Second-order stochastic dominance concepts. The first-order stochastic dominance (FSD) predicts that the risky alternative $F(w)$ is preferable to the alternative $G(w)$ if $[(G(w) - F(w)] \geq 0$ for all w

in $[a, b]$. The second order stochastic dominance (SSD) proposes that $F(w)$ is preferable to $G(w)$ if $\int_{a}^{b}[(G(w) - F(w)]dw \geq 0$ for all w in $[a, b]$. Despite the premise that the decision maker prefers more wealth to less, the FSD and SSD does not make any assumption about the underlying utility function shape. Also, FSD does not account if the producer is risk-loving, risk-neutral, or risk-averse. Although SDD assumes a risk aversion agent, there is no indication of risk aversion level.

To incorporate risk aversion in ranking risky alternative, Myers (1977) proposed the stochastic dominance with respect to a function (SDRF). According to SDRF, $F(w)$ is preferable to $G(w)$ if $\int_{r_L}^{r_U}[(G(w) - F(w)]u^L(w)dw \geq 0$, where we assume that lower risk aversion (r_L) and upper risk aversion (r_U) coefficients are 0 and 1, respectively. SDRF calculates the utility function for each w and then sum the weighted utilities to rank F and G. Richardson (2008) discussed the usefulness of SDRF when CDFs of alternative risk scenarios cross.

Hardaker et al. (2004) combined the certainty equivalence (CE) and SDRF concepts to propose stochastic efficiency with respect to a function (SERF). For a risky alternative, Freund (1956) defined CE as the difference between the expected wealth $E(W)$ and half of the risk aversion coefficient times the variance of wealth (V): $CE = E(W) - 0.5r_aV$. SERF evaluates CEs for many r_a between the lower and upper risk-aversion coefficient. SERF criteria to assess two risk scenarios F and G at each i risk aversion is the following: (1) $F(w)$ preferred to $G(w)$ at r_{ai} if $CE_{Fi} > CE_{Gi}$; (2) $F(w)$

indifferent to $G(w)$ at r_{ai} if $CE_{Fi} = CE_{Gi}$; and (3) $G(w)$ preferred to $F(w)$ at r_{ai} if $CE_{Fi} < CE_{Gi}$.

4.4. Results

Santa Brigida farm provided the data to estimate and calibrate the model. Oliveira et al. (2019) discussed the case of Santa Brigida, where a partnership between Embrapa and the property began in 2006. The goal of the partnership was to recover the farm production capacity. At the time, the farm had degraded land and low productivity indexes. For instance, the cattle were slaughtered over four years old. The farm located in Ipameri, Goias State, has an elevation of 800 meters above the sea level. The vast majority of soils consist of dark red latosol. The climate is tropical of mesothermal savannah with a rainy season from October to April and dry weather from May to September.

Embrapa brought the CLIS technology to the farm generating agronomic benefits, as shown in Table 4-2. Soybean productivity grew by over 40% in ten years. Corn showed similar behavior; the productivity raised from 5400 kg ha^{-1} in 2006/2007 to 11400 kg ha^{-1} in 2015/2016. As for animal production, the live weight gain went from 69 kg ha^{-1} in 2006/2007 to 730 kg ha^{-1}. To Oliveira et al. (2019), the farm’s performance is mainly due to the improvement of the chemical attributes of the soil and the increase in dry matter due to the presence of forage grasses in the rotation. The organic matter content of the soil increased as well, from 1.8% (18 mg dm^{-3}) in 2006 to 3.5% (35 mg dm^{-3}) in 2016.

Table 4-2 Crop and Livestock Yields

Crop Year	Soybean Integrated (Kg^1/ha^2)	Soybean (Kg/ha)	Corn Integrated (Kg/ha)	Corn (Kg/ha)	Livestock (Kg LW^3/ha)
2006/2007	2700	2800	5400	4824	69
2007/2008	2820	3200	6600	6000	111
2008/2009	3000	2902	7200	3787	167
2009/2010	3150	3200	8400	8000	222
2010/2011	3300	3000	10440	6000	333
2011/2012	3600	3300	11100	5400	472
2012/2013	3480	2880	9600	6600	447
2013/2014	3720	3294	10500	7200	554
2014/2015	3240	2700	10800	7200	730
2015/2016	3780	3300	11400	3869	730
Mean	3279	3058	9144	5888	384
StDev	370	228	2114	1426	243
CV	11	7	23	24	63
Min	2700	2700	5400	3787	69
Max	3780	3300	11400	8000	730

1 – Kilogram; 2 – Hectare; 3 – Live Weight
Source: Adapted from Oliveira et al. (2019)

Table 4-2 shows soybean and corn from the integrated system outperforming traditional system, especially in years with higher water deficit as in the 2012/2013 crop season. Santa Brigida Farm yield performance is comparable to that of Melloto et al. (2017). The author presented similar behavior investigating a property in Mato Grosso do Sul State showing the relevance of integrated system to risk management mainly in years of more severe drought as 2008/2009. Figure 4-1 depicts the results for soybean yields.

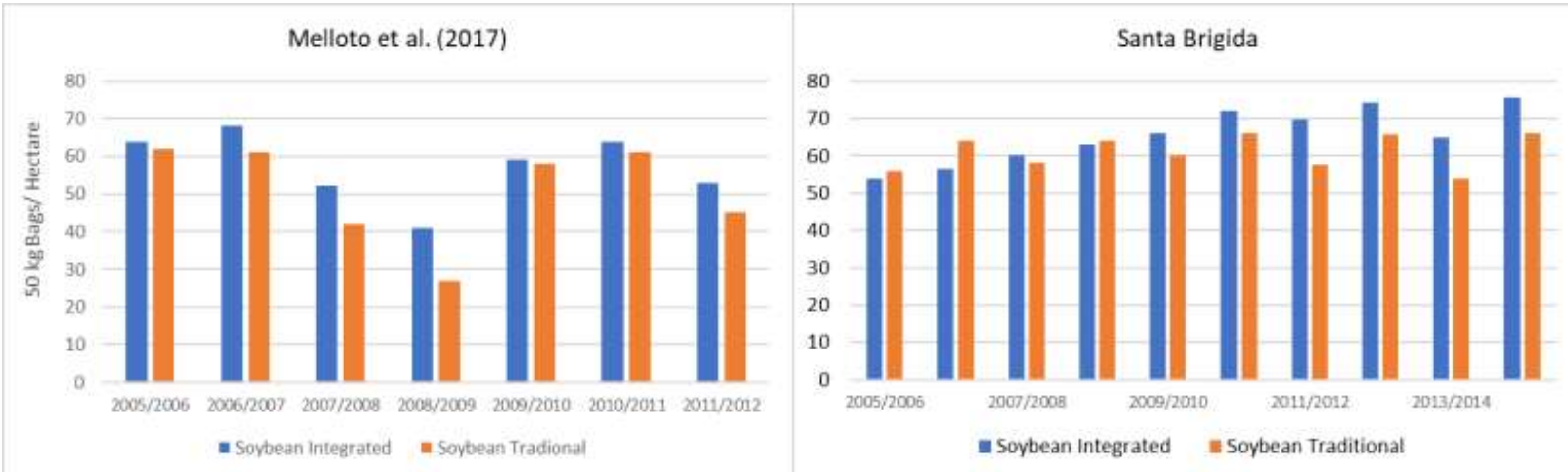

Figure 4-1 Soybean Yields: Integrated vs. Traditional
Sources: Adapted from Melloto et al. (2017) and Oliveira et al. (2019)

Figure 4-2 reveals that there has been a gradual rise in the price of the three commodities. From 2005 to 2018, corn appreciated by 99.2%, soybeans prices rose by 178.2%, while meat grew by 177.7%. Trend regression forecasted the prices, as it showed a better mean absolute percentage error (MAPE) than the exponential smoothing, moving average, and time series models. Note that the steeper growth in yields and prices leads to more vigorous growth projections.

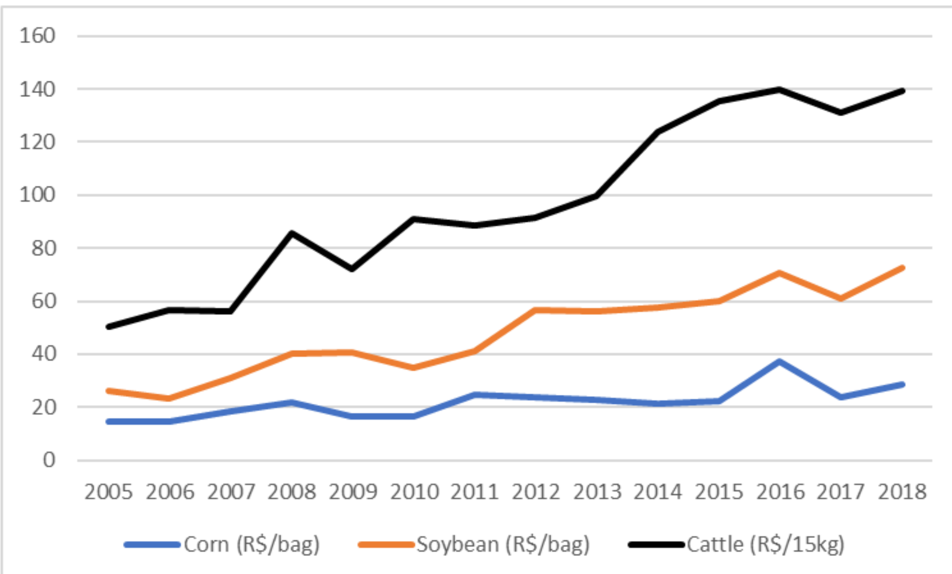

Figure 4-2 Corn, Soybean, and Cattle Prices Behavior
Source: Modified from Agrolink (2019)

Tables 4-3 brings a summary of 2018 Net Cash Farm Income (NCFI) per hectare. The net profit margin (net farm income over receipts) of integration farm scenarios (C and D) is higher than the traditional farm scenarios (A and B). For each R$1 of sale, scenarios A and B present a net profit of 0.30 and 0.29 cents, respectively. In parallel, scenarios C and D bring 0.39 and 0.40 cents of a net profit for each R$1 of sale.

Table 4-3 Net Farm Income per Hectare Under Four Scenarios: Average Values Assumed for 2018

	Scenarios			
	A	B	C	D
Receipts	4,776.23	7,952.06	9,449.97	12,102.65
Variable Cost	2,600.97	4,930.50	5,015.47	6,576.89
Fixed Cost	723.67	723.67	723.67	723.67
Total Cost	3,324.64	5,654.17	5,739.14	7,300.56
Net Farm Income	1,451.59	2,297.89	3,710.83	4,802.09

Notes: Receipts corresponds to the sum of revenues of each commodity, while expenses are the sum of fixed and variable costs. Net Farm Income is the difference between income and expenses.

The descriptive statistics (Table 4-4) show the crop-livestock integration scenarios (C and D) with higher expected net present value (NPV) than the alternative scenarios (A and B). In scenario D, where most of the area uses crop-livestock integration, the expected NPV/ha is R$ 33,913. In contrast, planting soybean and corn (Scenario B) yields an average NPV/ha of R$ 15,249.

Table 4-4 Descriptive Statistics: Scenarios and Net Present Value per Hectare

	Scenarios			
	A	B	C	D
Corn ha	0	1200	600	1000
Soybean ha	1500	1500	1500	1500
Cattle ha	0	0	600	1000
Mean	9083	15249	22026	33913
StDev	515	1141	1607	2105
CV	6	7	7	6
Min	7488	11870	17629	27781
Max	10433	19077	26144	39625

CLIS superior productivity gains combined with a cost structure similar to the traditional system helps to explain a higher average NPV of scenario D over scenario B. Another possible explanation for such a difference in averages lies in the fact that cattle production is added to the system under grazing feed and sale of animals during the offseason when the prices are higher.

The Gaussian approximation of the simulated NPV/ha probability density function (PDF) displays the variability behavior of the four scenarios, as shown in Figure 4-3. Scenarios with more products presented more considerable variability (standard deviations) and expected NPV.

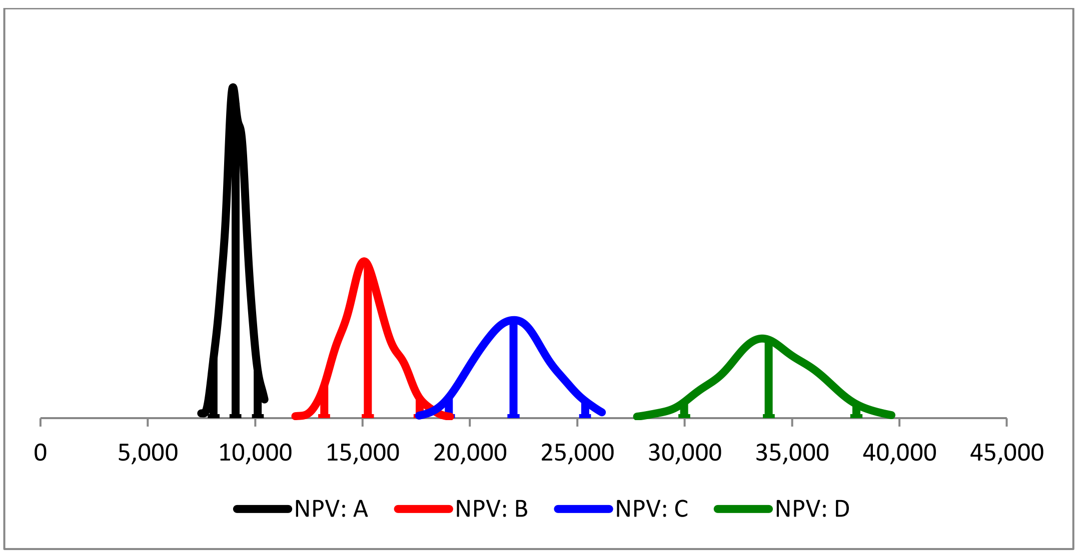

Figure 4-3 NPV/ha Scenarios PDF Approximations

Crop-livestock integration scenarios (C and D) are preferable to the traditional scenarios (A and B) when comparing the distribution of simulated NPV/ha. The cumulative distribution function (CDF) chart allows contrasting the full range of simulated outcomes for alternative scenarios. Figure 4-4 suggests that scenarios C and D should be preferred over the alternatives A and B because for each probability level crop-livestock scenarios are associated with higher NPV/ha.

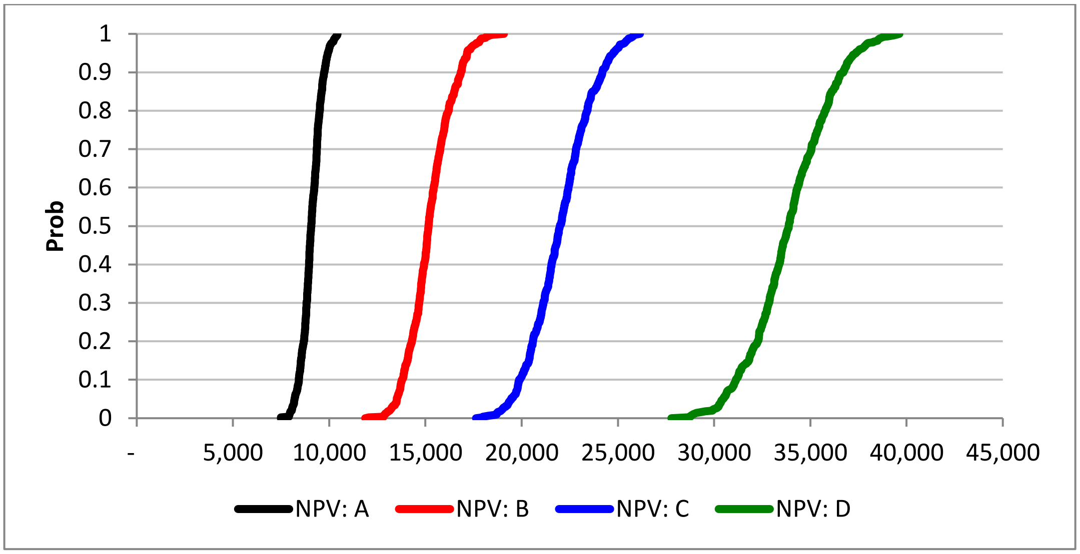

Figure 4-4 Comparison of 4 CDF Scenarios

When considering utility function to rank alternative scenarios, crop-livestock integrated scenarios are superior to the traditional scenarios. The analysis of stochastic dominance with respect to a function (SDRF) shows scenario D as most preferred being followed by scenarios C, B and A for both upper and lower relative risk aversion (RAC). Scenario D first-order stochastic dominates (FSD) and second-order stochastic dominates (SSD) over the other three alternative scenarios. Table 4-5 summarizes the stochastic dominance relationship between the four scenarios.

Table 4-5 First and Second-Order Stochastic Dominance

	NPV: A	NPV: B	NPV: C	NPV: D
NPV: A				
NPV: B	FSD/SSD			
NPV: C	FSD/SSD	FSD/SSD		
NPV: D	FSD/SSD	FSD/SSD	FSD/SSD	

Notes: FSD: First-Order Stochastic Dominance; SSD: Second-Order Stochastic Dominance. The tables read by row, for instance, row 3 show NPV scenario C first and second-order stochastic dominates scenario A.

Figure 4-5 graphs, under a negative exponential utility function, the certainty equivalent (CE) over a range of absolute risk-averse coefficient for all the alternative scenarios. The result shows that a rational decision-maker would engage in risky farm activity instead of opting for a risk-free alternative investment because CE lines remain positive over the absolute risk aversion coefficient (ARAC) span. To Richardson (2008), the ARAC range for SERF should be (0, 4/Z), where Z is the average wealth. Unlike the author, we adopt a larger ARAC interval, that is, instead of (0, 0.00026) we use (0, 0.001). Regardless of the level of risk preference (risk-neutral to risk aversion), the crop-livestock integration system scenarios are preferred to traditional farming scenarios.

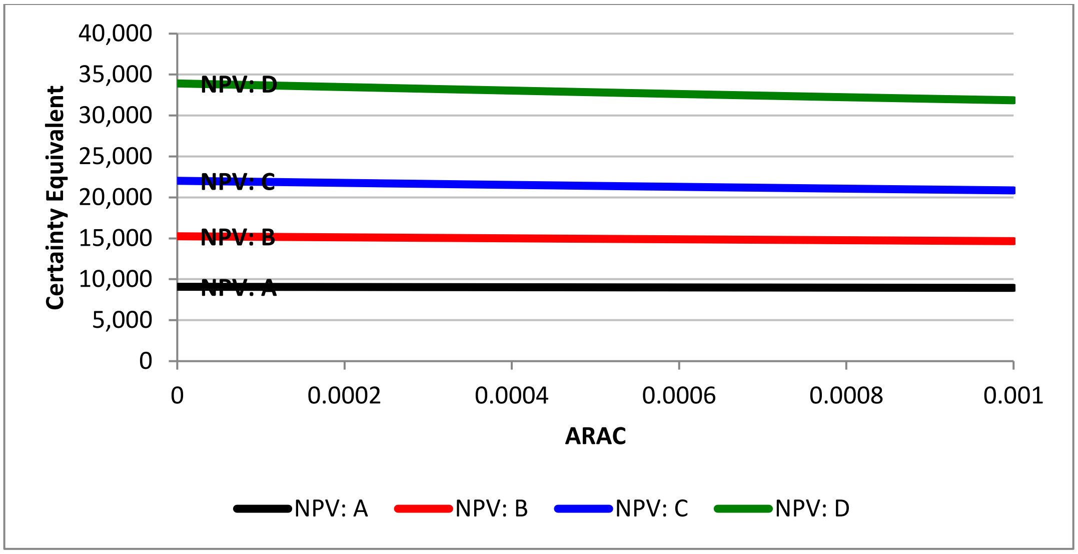

Figure 4-5 NPV/ha Stochastic Efficiency with Respect to a Function (SERF) Under Negative Exponential Utility Function

According to all four different ranking approach, the crop-livestock integration scenario would be preferable to plant only soybean or soybean and corn. The positive net present value indicates that crop-livestock generates economics value to the farmer. The growth of the integration systems area in Brazil reflects the economics incentives.

4.5. Conclusion

We documented the economic feasibility of a CLIS contrasting hypothetical scenarios. The findings indicate crop-livestock integration scenarios with higher net present value than the traditional alternatives investigated. Moreover, CLIS is ranked first under different approaches such as first-order stochastic dominance, second-order stochastic dominance, stochastic dominance with respect to a function, and stochastic efficiency with respect to a function. Overall, the results illustrate that it is possible to increase food production sustainably and, at the same time, increase economic value.

The results are relevant to assist the farmers in deciding what to plant. Policy-makers can use the model to support their decisions on agricultural subsidy decisions. Future studies may include different configurations of the integrations system, for instance, crop-livestock-forest. Another possible investigation may look at different crops or livestock, such as sheep or sorghum.

4.6. References

Agrolink. (2019). Cotacoes. Retrieved from https://www.agrolink.com.br/cotacoes/ [Accessed June 09, 2019].

Balbino, L. C., Barcellos, A. O., & Stone, L. F. (2011). *Marco Referencial: Integração Lavoura-Pecuária-Floresta*. Brasília, DF: Embrapa.

Balbino, L. C., Kichel, A. N., Bungenstab, D. J., & de Almeida, R. G. (2019). Sistemas de Integração: Conceitos, Considerações, Contribuições e Desafios. In D. J. Bungenstab, R. G. de Almeida, V. A. Laura, L. C. Balbino, & A. D. Ferreira (Eds.), *ILPF : Inovação com Integração de Lavoura, Pecuária e Floresta* (pp. 31-48). Brasilia: Embrapa.

Balbino, L. C., Porfirio, V., Kichel, A. N., Rosinha, R. O., & Costa, J. A. A. d. (2011). *Manual Orientador para Implantação de Unidades de Referência Tecnológica de Integração Lavoura-Pecuária-Floresta URT iLPF*. Embrapa Cerrados. Documentos, 303. Brasilia.

Bell, L. W., & Moore, A. D. (2012). Integrated Crop-Livestock Systems in Australian Agriculture: Trends, Drivers and Implications. *Agricultural Systems, 111*, 1-12. doi:10.1016/j.agsy.2012.04.003

Brealey, R., Myers, S., & Allen, F. (2019). *Principles of Corporate Finance* (13th ed.): McGraw-Hill Education.

Brighenti, A. M., Muller, M. D., Martins, C. E., da Rocha, W. S. D., Andrade, P. J. M., Sobrinho, F. d. S., . . . Machado, A. F. (2019). Manejo de Plantas Daninhas e Forrageiras em Sistemas de Integração Lavoura-Pecuária-Floresta. In *ILPF: Inovacao com integracao de lavoura, pecuaria, floresta*. Brasilia: Embrapa.

Calil, Y. C. D., & Ribera, L. (2019). Brazil’s Agricultural Production and Its Potential as Global Food Supplier. *Choices, 34*, 1-12.

Climate-Data. (2019). Goiania Climate. Retrieved from https://en.climate-data.org/south-america/brazil/goias/goiania-2191/ [Accessed June 09, 2019].

Conab. (2019). Custos de Producao. Retrieved from https://www.conab.gov.br/info-agro/custos-de-producao [Accessed December 19, 2019].

de Oliveira, I. P., Kluthcouski, J., Yokoyama, L. P., Dutra, L. G., de A. PORTES, T., da SILVA, A. E., . . . Guimaraes, C. M. (1996). *Sistema Barreirão: Recuperação/Renovação de Pastagens Degradadas em Consórcio com Culturas Anuais*. Goiânia: EMBRAPA-CNPAF-APA.

Dias -Filho, M. B. (2014). *Diagnóstico das Pastagens no Brasil.* Retrieved from: http://ainfo.cnptia.embrapa.br/digital/bitstream/item/102203/1/DOC-402.pdf [Accessed May 14, 2019].

Embrapa. (2019). Integração Lavoura-Pecuária-Floresta. Retrieved from: https://www.embrapa.br/tema-integracao-lavoura-pecuaria-floresta-ilpf [Accessed April 29, 2019].

FAO. (2012). World Agriculture: towards 2030/2050 – The 2012 Revision. Retrieved from http://www.fao.org/global-perspectives-studies/resources/detail/en/c/411108/ [Accessed March 10, 2019].

FAO. (2019). How to Feed the World in 2050 Retrieved from http://www.fao.org/fileadmin/templates/wsfs/docs/expert_paper/How_to_Feed_the_World_in_2050.pdf [Accessed March 10, 2019].

Freund, R. J. (1956). The Introduction of Risk into a Programming Model. *Econometrica, 24*, 253-261.

Garrett, R. D., Niles, M. T., Gil, J. D. B., Gaudin, A., Chaplin-Kramer, R., Assmann, A., . . . Valentim, J. (2017). Social and Ecological Analysis of Commercial Integrated Crop Livestock Systems: Current Knowledge and Remaining Uncertainty. *Agricultural Systems, 155*, 136-146. doi:10.1016/j.agsy.2017.05.003

Graham, J., & Harvey, C. (2002). How CFOs Make Capital Budgeting and Capital Structure Decisions. *Journal of Applied Corporate Finance, 15*, 8-23.

Hardaker, J. B., Richardson, J. W., Lien, G., & Schumann, K. D. (2004). Stochastic Efficiency Analysis with Risk Aversion Bounds: a Simplified Approach. *Australian Journal of Agricultural and Resource Economics, 48*(2), 253-270. doi:DOI 10.1111/j.1467-8489.2004.00239.x

Hardar, J., & Russel, W. R. (1969). Rules for Obtaining Uncertain Prospects. *American Economic Review, 59*, 25-34.

IBGE. (2018). Censo Agro 2017. Retrieved from https://censos.ibge.gov.br/agro/2017/ [Accessed May 10, 2019].

Kichel, A. N., & Miranda, C. H. B. (2001). *Sistema de Integração Agricultura x Pecuária*. Retrieved from https://www.embrapa.br/gado-de-corte/busca-de-publicacoes/-/publicacao/325259/sistema-de-integracao-agricultura-x-pecuaria [Accessed May 12, 2019].

Kluthcouski, J., Pacheco, A. R., Teixeira, S. M., & Oliveira, E. T. d. (1991). *Renovação de Pastagens de Cerrado com Arroz: I. Sistema Barreirão.* Retrieved from Goiânia: http://ainfo.cnptia.embrapa.br/digital/bitstream/CNPAF/1907/1/doc_33.pdf [Accessed April 15, 2019].

Maisashvili, A., Bryant, H. L., & Richardson, J. W. (2016). Economic Feasibility of Tobacco Leaves for Biofuel Production and High Value Squalene. *International Food and Agribusiness Management Review, 19*(4), 145-161. doi:10.22434/Ifamr2015.0179

MAPA. (2019). Plano ABC - Agricultura de Baixa Emissão de Carbono. Retrieved from http://www.agricultura.gov.br/assuntos/sustentabilidade/plano-abc/plano-abc-agricultura-de-baixa-emissao-de-carbono [Accessed June 25, 2019].

Melloto, A. M., Lourencao, A. L. F., Grigolli, J. F. J., & Gitti, D. C. (2017). Implatacao do Consorcio Milho Capins em Mato Grosso do Sul: Principais Aspectos. In A. L. F. Lourencao, J. F. J. Grigolli, A. M. Melloto, & D. C. Gitti (Eds.), *Tecnologia e Producao: Milho Safrinha 2016* (pp. 148). Maracaju, MS: Fundacao MS.

Monge, J. J., Ribera, L. A., Jifo, J. L., & da Silva, J. A. (2014). Economics of Lignocellulosic Ethanol Production from Energy Cane and Sweet Sorghum in South Texas. *Journal of Agricultural and Applied Economics, 46*, 457-485.

Myers, J. (1977). Choice Among Distributions. *Journal of Economic Theory, 14*, 326-336.

Nicodemo, M. L. F., & Primavesi, O. (2019). Serviços Ambientais em Sistemas Silvipastoris. In D. J. Bungenstab, R. G. de Almeida, V. A. Laura, L. C. Balbino, & A. D. Ferreira (Eds.), *ILPF : Inovação com Integração de Lavoura, Pecuária e Floresta /* (pp. 139-152). Brasilia: Embrapa.

Niles, M. T., Garrett, R. D., & Walsh, D. (2017). Ecological and Economic Benefits of Integrating Sheep into Viticulture Production. *Agronomy for Sustainable Development, 38*(1). doi:ARTN 110.1007/s13593-017-0478-y

Oliveira, P., Freitas, R. J., Kluthcouski, J., Ribero, A. A., Cordeiro, L. A. M., Teixeira, L. P., . . . Balbino, L. C. (2019). Integracao Lavoura-Pecuaria-Floresta: Caso de Sucesso da Fazenda Santa Brigida, no Estado de Goias. In D. J. Bungenstab, R. G. Almeida, A. L. Valdemir, L. C. Balbino, & A. D. Ferreira (Eds.), *ILPF Inovacao com Integracao de Lavoura, Pecuaria e Floresta.* (pp. 743-753). Brasilia: Embrapa.

Outlaw, J. L., Ribera, L. A., Richardson, J. W., Silva, J. G. d., Bryant, H. L., & Klose, S. L. (2007). Economics of Sugar-Based Ethanol Production and Related Policy Issues. *Journal of Agricultural and Applied Economics, 39,* 357-363.

Paciullo, D. S. C., & Gomide, C. A. d. M. (2019). Manejo de Pastagens Tropicais em Sistemas Silvipastoris. In *ILPF: Inovacao com Integracao Lavoura, Pecuaria e Floresta*. Brasilia: Embrapa.

Purvis, B., Mao, Y., & Robinson, D. (2019). Three Pillars of Sustainability: in Search of Conceptual Origins. *Sustainability Science, 14*(3), 681-695. doi:10.1007/s11625-018-0627-5

Rezende, M. L., & Richardson, J. W. (2015). Economic Feasibility of Sugar and Ethanol Production in Brazil Under Alternative Future Prices Outlook. *Agricultural Systems, 138,* 77-87. doi:10.1016/j.agsy.2015.05.004

Richardson, J. (2008). *Simulation for Applied Risk Management: With an Introduction to Simetar*. College Station, Texas, US: Department of Agricultural Economics, Texas A & M University,.

Richardson, J., Klose, S. L., & Gray, A. W. (2000). An Applied Procedure for Estimating and Simulating Multivariate Empirical (MVE) Probability Distributions in Farm Level Risk Assessment and Policy Analysis. *Journal of Agricultural and Applied Economics, 32*, 299-315.

Richardson, J. W., Herbst, B., Outlaw, J. L., & Gill, C. (2007). Including Risk in Economic Feasibility Analyses: the Case of Ethanol in Texas. *Journal of Agribusiness, 25*, 115 -132.

Seguy, L., Kluthcouski, J., Silva, J. G. d., Blumenschein, F. N., & Dall'acqua, F. M. (1984). *Técnicas de Preparo do Solo: Efeitos na Fertilidade e na Conservação do Solo, nas Ervas Daninhas e na Conservação de Agua.* Retrieved from:

http://ainfo.cnptia.embrapa.br/digital/bitstream/CNPAF-2009-09/1357/1/circ_17.pdf [Accessed May 14, 2019].

Sulc, R. M., & Franzluebbers, A. J. (2014). Exploring Integrated Crop-Livestock Systems in Different Ecoregions of the United States. *European Journal of Agronomy*, *57*, 21-30. doi:10.1016/j.eja.2013.10.007

United Nations. (2019). Paris Agreement - Status of Ratification. Retrieved from https://unfccc.int/process/the-paris-agreement/status-of-ratification [Accessed June 24, 2019].

Veysset, P., Lherm, M., Bebin, D., & Roulenc, M. (2014). Mixed Crop-Livestock Farming Systems: a Sustainable Way to Produce Beef? Commercial Farms Results, Questions and Perspectives. *Animal*, *8*(8), 1218-1228. doi:10.1017/s1751731114000378

Zapata, S. D., Ribera, L. A., & Palma, M. A. (2017). Effect of Production Parameters on the Economic Feasibility of a Biofuel Enterprise. *Journal of Agricultural and Applied Economics, 49*(3), 347-362. doi:10.1017/aae.2016.42

5. CONCLUSIONS

The hedonic analysis of the factors that explain Brazilian purebred Nellore sold at auction prices indicates cattle buyers' preferences for precocity characteristics. So, it can be expected from the Brazilian farms a more productive herd, steers finishing early and heifers calving early. Auction type, lot size, and reputation are important factors in marketing animals. Not only genetics but also morphological characteristics play an essential role in explaining the prices.

EU-Mercosur Free Trade Agreement may lead to Mercosur countries exporting more chicken, cattle, pig, cotton, soybean, wheat, and maize while having relatively small welfare gains. On the other hand, the European countries may reduce their exports to their fellow countries, but with more substantial welfare gains, especially in the meat sector.

The Crop-livestock integration system generates more economic value than the traditional farming system for Brazilian producers. Thus, this sustainable technology may spread throughout the country, recovering degraded lands, and increasing productivity. Therefore, Brazil should further enhance its competitiveness in food production.

APPENDIX A

Table A-1 Sector Description

Item Code	Item	Description	HS12 Code	CPC Code
1058	Meat, chicken	Fresh, chilled or frozen. May include all types of poultry meat if national statistics do not report separate data.	020711, 020712, 020713, 020714, 020760	21121
867	Meat, cattle	Meat of bovine animals, fresh, chilled or frozen, with bone in. Commontrade names are beef and veal.	020110, 020120, 020210, 020220	21111.01
1035	Meat, pig	Meat, with the bone in, of domestic or wild pigs (e.g. wild boars),whether fresh, chilled or frozen.	020311, 020312, 020319, 020321, 020322, 020329	21113.01
767	Cotton lint	Gossypium spp. Fibres from ginning seed cotton that have not been carded or combed. Trade data also include fibres that have been cleaned, bleached, dyed or rendered absorbent.	520100	1921.02
236	Soybeans	Glycine soja. The most important oil crop. Also widely consumed as a bean and in the form of various derived products because of its high protein content, e.g. soya milk, meat, etc.	120110, 120190	141
15	Wheat	Triticum spp.: common (T. aestivum) durum (T. durum) spelt (T. spelta). Common and durum wheat are the main types. Among common wheat, the main varieties are spring and winter, hard and soft, and red and white. At the national level, different varieties should be reported separately, reflecting their different uses. Used mainly for human food.	100111, 100119, 100191, 100199	111
56	Maize	Zea mays Corn, Indian corn, mealies. A grain with a high germ content. At the national level, hybrid and ordinary maize should be reported separately owing to widely different yields and uses. Used largely for animal feed and commercial starch production.	100510, 100590	112

HS - Harmonizing System; CPC - Central Product Classification.

Table A-2 EU–Mercosur RTA Effects on Exports to EU (1 = no change)

Exporter	Chicken	Cattle	Pig	Cotton	Soybeans	Wheat	Maize
ARG	1.5859	1.6188	1.9623	1.2782	0.8622	1.3494	1.0602
AUS	0.4577		0.9998	0.9670		0.9959	0.8770
AUT	0.8684	0.9468	1.0002	0.9944	1.0758	0.9985	0.9705
BEL	0.7833	0.9472	1.0003	0.9938	1.0725	0.9984	0.9742
BGR	0.8265	0.7683		0.9793		0.9926	0.9618
BRA	1.4718	1.5138	2.0566	1.2916	0.8971	1.3141	1.0404
CAN		0.8069		0.9890	1.1754	0.9919	0.8543
CHL	0.5601	0.7949	0.9974		1.3250	0.9755	0.8706
CHN			1.0000	0.9837	1.3531	0.9871	0.9000
COL							0.8990
CYP	0.8277	0.9632	1.0002	0.9925	1.0033	0.9975	0.9690
CZE	0.8522	0.9555	1.0002	0.9980	1.0432	0.9974	0.9712
DEU	0.8023	0.9502	1.0002	0.9961	1.0524	0.9976	0.9733
DNK	0.8437	0.9556	1.0002	0.9989	1.0294	0.9967	0.9789
DZA							
EGY				0.9683			0.9053
ESP	0.8242	0.9534	1.0003	0.9842	1.0912	0.9945	0.9721
EST	0.8784	0.9569	1.0002	0.9994	1.0439	0.9934	0.9795
FIN	0.8823	0.9630	1.0002	0.9991	1.0425	0.9970	0.9733
FRA	0.8293	0.9566	1.0002	0.9906	1.0745	0.9968	0.9685
GBR	0.8548	0.9465	1.0002	0.9896	1.1959	0.9970	0.9705
GRC	0.8674	0.9665	1.0002	0.9883	1.0123	0.9981	0.9769
HRV	0.6013	0.9787	1.0002	0.9980	1.3106	0.9983	0.9892
HUN	0.8118	0.9434	1.0002	0.9952	1.0445	0.9968	0.9645
IDN				0.9740			0.8775
IND				0.9774	1.2022	0.9901	0.8952
IRL	0.8581	0.9362	1.0002	1.0007	1.0812	0.9977	0.9757
IRN			1.0000	0.9655		0.9939	
ISR	0.7982			0.9818	1.2553		0.9219
ITA	0.8249	0.9615	1.0002	0.9935	1.0981	0.9989	0.9763
JPN	0.4110			0.9767	1.2823		
KAZ				0.9945		0.9973	
KOR					1.3498		
LTU	0.8507	0.9450	1.0001	0.9977	1.0468	0.9935	0.9809
LUX	0.8672	0.9527	1.0002	0.9979	1.0704	0.9983	0.9730
LVA	0.8709	0.9348	1.0002	0.9970	1.0445	0.9929	0.9840
MAR							0.8891
MEX				0.9994		0.9956	0.8745
MLT	0.8643	0.9679	1.0002	1.0000	1.0345	0.9997	0.9736

Table A-2 Continued

Exporter	Chicken	Cattle	Pig	Cotton	Soybeans	Wheat	Maize
NLD	0.8234	0.9523	1.0002	0.9964	1.0714	0.9978	0.9684
PAK				0.9788			0.9065
PER				0.9737	1.3362	0.9695	0.8834
PHL							0.8912
POL	0.8130	0.9420	1.0002	0.9977	1.0545	0.9980	0.9736
PRT	0.8275	0.9646	1.0002	0.9911	1.0984	0.9960	0.9707
PRY				1.2783	0.9453		1.0491
ROU		0.8080		0.9848	1.3191	0.9934	0.9864
RUS	0.4561		1.0001	0.9632		0.9953	0.9771
SVK	0.8458	0.9513	1.0001	0.9978	1.0367	0.9979	0.9710
SVN	0.8318	0.9569	1.0001	0.9980	1.1759	0.9979	0.9743
SWE	0.8826	0.9578	1.0002	0.9986	1.0378	0.9959	0.9782
THA	0.7530	0.7555		0.9673	1.4842		0.8994
TUR				0.9788		0.9987	0.9526
UKR	0.5970			0.9745	1.2291	0.9936	0.9623
URY	1.2548	1.6011			0.7792		1.0252
USA	0.5400	0.8100	0.9999	0.9769	1.2615	0.9919	0.8777
VEN							
ZAF			1.0000	0.9695			0.8791

Table A-3 EU–Mercosur RTA Effects on Overall Trade (1 = no change)

Exporter	Chicken	Cattle	Pig	Cotton	Soybean	Wheat	Maize
ARG	1.1027	1.0174	1.0013	1.0046	0.9875	1.0132	1.0082
AUS	1.0645	1.0141	1.0003	1.0014	1.0037	0.9999	0.9946
AUT	0.8685	0.9468	1.0002	0.9994	1.0702	0.9986	0.9716
BEL	0.8434	0.9473	1.0002	0.9971	1.0725	0.9984	0.9747
BGR	0.8675	1.0187	1.0001	1.0007	1.0101	0.9963	0.9764
BRA	1.1072	1.0277	0.9858	1.0062	0.9695	1.0187	1.0146
CAN	1.0290	1.0112	1.0003	1.0012	1.0442	1.0001	1.0012
CHL	0.9865	1.0110	1.0011	1.0015	1.0018	1.0054	0.9977
CHN	1.0335	1.0107	1.0002	1.0010	0.9927	1.0005	1.0032
COL	0.9978	1.0084	1.0002	1.0009	1.0082	1.0032	1.0021
CYP	0.8277	0.9632	1.0002	0.9925	1.0033	0.9985	0.9756
CZE	0.8528	0.9555	1.0002	0.9980	1.0432	0.9980	0.9712
DEU	0.8521	0.9509	1.0002	0.9971	1.0524	0.9981	0.9736
DNK	0.8739	0.9581	1.0002	1.0007	1.0294	0.9967	0.9789
DZA	0.9978	0.9636	1.0001	1.0002	1.0254	0.9989	1.0025
EGY	1.0787	1.0207	1.0000	1.0002	1.0068	0.9995	1.0013
ESP	0.8249	0.9538	1.0003	0.9963	1.0911	0.9951	0.9722
EST	0.8784	0.9569	1.0002	0.9994	1.0439	0.9934	0.9795
FIN	0.9016	0.9630	1.0002	0.9991	1.0425	0.9970	0.9758
FRA	0.8481	0.9566	1.0002	0.9983	1.0729	0.9978	0.9692
GBR	0.8614	0.9465	1.0002	0.9970	1.0451	0.9970	0.9768
GRC	0.8681	0.9665	1.0002	1.0005	1.0017	0.9981	0.9773
HRV	0.9686	0.9560	1.0001	0.9985	0.9785	0.9992	0.9694
HUN	0.8276	0.9435	1.0002	0.9955	1.0263	0.9979	0.9662
IDN	0.8837	1.0105	1.0002	1.0009	1.0095	1.0000	1.0031
IND	1.0214	1.0137	1.0002	1.0013	1.0232	0.9997	1.0041
IRL	0.8664	0.9405	1.0002	1.0007	1.0812	0.9977	0.9757
IRN	0.9978	1.0000	1.0002	1.0016	1.0056	1.0000	0.9998
ISR	0.7982	0.9924	1.0000	0.9986	1.0174	0.9993	0.9926
ITA	0.8292	0.9617	1.0002	0.9952	1.0981	0.9989	0.9763
JPN	1.0728	1.0095	1.0002	1.0011	1.0087	1.0002	1.0018
KAZ	1.0116	1.0038	1.0002	0.9976	1.0388	0.9986	0.9755
KOR	1.0254	1.0105	1.0002	1.0014	0.9938	1.0002	1.0027
LTU	0.8538	0.9495	1.0001	0.9977	1.0468	0.9938	0.9809
LUX	0.8672	0.9527	1.0002	0.9979	1.0704	0.9983	0.9730
LVA	0.8766	0.9348	1.0002	0.9979	1.0445	0.9929	0.9840
MAR	1.0761	1.0080	1.0002	0.9987	1.0009	0.9993	1.0018
MEX	1.0106	1.0125	1.0002	1.0011	1.0106	1.0001	1.0016
MLT	0.8643	0.9679	1.0002	1.0000	1.0345	0.9997	0.9736

Table A-3 Continued

Exporter	Chicken	Cattle	Pig	Cotton	Soybean	Wheat	Maize
NLD	0.8314	0.9525	1.0002	0.9986	1.0714	0.9985	0.9766
PAK	0.9978	1.0103	1.0000	1.0015	1.0101	0.9996	0.9988
PER	1.0418	1.0122	1.0000	0.9998	0.9973	1.0034	1.0040
PHL	1.0250	1.0103	1.0002	1.0011	1.0092	1.0012	1.0039
POL	0.8195	0.9421	1.0002	0.9977	1.0545	0.9982	0.9736
PRT	0.8275	0.9646	1.0002	0.9911	1.0984	0.9961	0.9707
PRY	1.0491	1.0161	1.0000	1.0045	0.9558	1.0162	1.0112
ROU	1.0052	1.0007	1.0000	0.9982	1.0391	0.9974	0.9674
RUS	1.0056	1.0120	1.0002	0.9968	1.0402	0.9992	0.9807
SVK	0.8463	0.9513	1.0001	0.9978	1.0367	0.9980	0.9713
SVN	0.8419	0.9569	1.0001	0.9980	1.0813	0.9988	0.9743
SWE	0.8844	0.9578	1.0002	0.9987	1.0378	0.9963	0.9782
THA	0.8732	1.0065	1.0002	1.0010	0.9886	0.9996	1.0027
TUR	0.9978	1.0000	1.0000	1.0006	1.0087	0.9989	0.9785
UKR	0.9549	1.0160	1.0001	0.9988	1.0631	0.9992	0.9753
URY	1.1750	1.0267	1.0000	1.0014	0.9840	1.0161	1.0058
USA	1.0217	1.0105	1.0003	1.0014	1.0142	1.0004	1.0020
VEN	1.0794	1.0063	1.0000	1.0000	0.9799	1.0006	1.0036
ZAF	1.0608	1.0113	1.0002	1.0015	0.9988	1.0035	1.0059

Table A-4 EU–Mercosur RTA Effects on Welfare (1 = no change)

Exporter	Chicken	Cattle	Pig	Cotton	Soybean	Wheat	Maize
ARG	1.0095	1.0006	1.0000	0.9987	0.9970	1.0132	1.0982
AUS	1.0003	1.0005	1.0000	1.0006	1.0003	0.9999	0.9999
AUT	1.0488	0.9858	1.0000	1.0019	0.9659	0.9996	0.9961
BEL	0.8139	0.9910	1.0002	1.0015	0.9351	1.0012	1.0232
BGR	0.9791	0.9967	1.0000	0.9997	0.9963	0.9968	0.9956
BRA	1.0273	1.0006	1.0000	1.0022	0.9585	0.9910	1.0007
CAN	0.9979	1.0001	1.0001	0.9986	1.0211	1.0001	0.9996
CHL	0.9946	1.0000	1.0000	0.9980	1.0133	0.9973	0.9947
CHN	0.9987	1.0000	1.0000	0.9997	1.0060	1.0000	1.0000
COL	1.0000	1.0003	1.0000	0.9993	0.9912	0.9958	0.9985
CYP	1.0100	1.0018	1.0000	0.9785	0.9963	1.0012	1.0099
CZE	1.0388	1.0044	1.0000	1.0020	0.9631	0.9992	0.9915
DEU	1.0362	0.9932	1.0000	1.0034	0.9290	0.9997	1.0078
DNK	0.9620	1.0065	1.0002	1.0005	0.9795	0.9997	1.0237
DZA	1.0000	1.0001	1.0000	1.0024	0.9671	1.0009	0.9967
EGY	0.9984	0.9999	1.0000	1.0001	0.9915	1.0002	0.9995
ESP	1.0146	0.9936	1.0001	0.9924	0.8798	1.0035	1.0186
EST	1.0462	1.0010	1.0000	1.0004	0.9502	0.9993	1.0235
FIN	1.0084	1.0006	1.0000	0.9992	0.9460	1.0000	1.0022
FRA	0.9992	0.9993	1.0000	1.0015	0.9420	0.9982	0.9605
GBR	1.0734	1.0024	0.9999	0.9975	0.9166	0.9998	1.0265
GRC	1.0379	1.0242	0.9999	1.0057	0.8781	1.0006	1.0051
HRV	1.0053	0.9998	1.0000	1.0004	1.0089	0.9999	0.9955
HUN	0.9423	0.9878	1.0000	1.0000	1.0094	0.9978	0.9782
IDN	1.0000	1.0000	1.0000	0.9982	0.9938	1.0001	0.9995
IND	1.0000	1.0001	1.0000	1.0003	1.0000	1.0000	1.0000
IRL	1.0876	0.9884	1.0000	0.9998	0.9244	1.0009	1.0118
IRN	1.0000	1.0000	1.0000	1.0001	1.0000	1.0000	1.0000
ISR	0.9991	1.0001	1.0000	0.9983	0.9978	1.0008	1.0066
ITA	0.9828	1.0107	0.9999	1.0095	0.9032	1.0006	1.0042
JPN	0.9812	1.0000	0.9999	0.9980	0.9917	0.9999	0.9980
KAZ	0.9934	1.0000	1.0000	0.9971	0.9950	0.9996	0.9994
KOR	0.9982	0.9991	1.0000	0.9979	1.0022	0.9997	0.9966
LTU	1.0147	0.9948	1.0000	1.0004	1.0012	0.9989	1.0237
LUX	1.1507	1.0091	0.9999	1.0024	1.0010	1.0006	1.0186
LVA	1.0688	0.9874	0.9999	0.9927	0.9505	0.9969	1.0136
MAR	0.9999	1.0000	1.0000	1.0033	0.9988	1.0002	0.9981
MEX	0.9989	1.0001	1.0000	0.9990	0.9863	0.9998	0.9995
MLT	1.1377	1.0058	1.0000	1.0000	0.9965	1.0002	1.0320

Table A-4 Continued

Exporter	Chicken	Cattle	Pig	Cotton	Soybean	Wheat	Maize
NLD	0.8795	0.9954	1.0001	0.9998	0.9497	1.0016	1.0249
PAK	1.0000	1.0000	1.0000	0.9995	0.9868	1.0000	1.0001
PER	0.9999	1.0000	1.0000	1.0000	1.0046	0.9961	0.9972
PHL	0.9996	1.0000	1.0000	0.9987	0.9880	0.9984	0.9997
POL	0.9436	0.9623	1.0000	1.0018	0.9525	1.0000	1.0030
PRT	1.0069	1.0109	0.9999	1.0156	0.8923	1.0021	1.0245
PRY	0.9999	1.0036	1.0000	1.0078	0.9196	1.0143	1.1144
ROU	0.9987	0.9998	1.0000	1.0001	1.0082	0.9994	0.9984
RUS	0.9984	0.9983	1.0000	1.0019	0.9999	0.9998	1.0035
SVK	1.0308	1.0024	1.0000	0.9964	0.9808	0.9996	0.9704
SVN	0.9484	1.0001	0.9999	1.0017	0.9703	1.0009	1.0149
SWE	1.0778	1.0024	0.9999	1.0010	0.9340	0.9989	1.0207
THA	1.0000	1.0000	1.0000	0.9988	1.0137	0.9998	1.0002
TUR	1.0000	1.0000	1.0000	0.9998	0.9891	1.0000	0.9997
UKR	1.0039	1.0001	1.0000	1.0001	1.0348	0.9996	0.9974
URY	1.0001	1.0024	1.0000	0.9971	0.5381	1.0044	0.9964
USA	1.0018	1.0000	1.0000	1.0263	1.0067	1.0003	1.0005
VEN	0.9977	0.9997	1.0000	1.0000	1.0168	0.9992	0.9999
ZAF	0.9942	1.0000	1.0000	1.0050	1.0003	0.9989	0.9991