BRAZILIAN DAIRY MODEL: IMPACTS OF AGRICULTURAL POLICIES AND EXOGENOUS SHOCKS

A Dissertation

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ABSTRACT

Brazil is the fourth largest country in milk production with numerous small scale family farms. During the last three decades many transformations were in place that includes price regulation, dairy policies and international competition on the entire supply chain. Understanding how the dairy sector reacts to exogenous shocks and policy changes is of interest. This research aims to analyze economic consequences of exogenous shocks and policy changes in the Brazilian dairy sector. Impacts of changes in gross domestic product, subsidized interest rate, milk price support, renewable fuel standard requirement in the United States, and sugar cane acreage in Brazil on the entire sector is considered for a 10-year forecasts ending in 2022.

A structural econometric model of the Brazilian dairy sector is used to analyze the consequences of changes in policies and other variables of interest on the production, consumption, and milk prices. A stochastic approach is also developed that incorporates risk into the model. Data from 1980 to 2012 are used to estimate the system of equations. Annual equilibrium prices are solved by minimizing the squared difference between supply and demand for four different markets: cheese, butter, milk powder, and fresh dairy products.

This is the first model developed for the Brazilian dairy sector that allows for policy analysis. The findings suggest that the sector is not very responsive to changes in exogenous variables. Shocks from the demand side appear to have greater impacts on milk prices and production than shocks from the supply side. Contributions to the

agricultural economic literature, policy makers, private companies, and future researches are expected.

DEDICATION

I would like to dedicate this dissertation to Clê, Murilo, and Henrique. Clê, obrigado pelo seu apoio incondicional em todos os momentos. Sem você aqui, tenho certeza que este momento não teria chegado.

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NOMENCLATURE

AFPC	Agriculture and Food Policy Center
APEX-BRAZIL	Brazilian Export and Investment Promotion Agency
BNDES	National Bank of Social Development
CCT	Conditional Cash Transfer
CDF	Cumulative Distribution Function
CEPEA	Center for Advanced Studies on Applied Economics
CET	Common External Tariff
CONAB	Brazilian National Food Supply Agency
CPIDEF	Consumer Price Index Deflator
DYCOF	Number of Dairy Cows
DYMKPRD	Milk Production
DYMPPC	Milk Production Per Cow
FAO	Food and Agriculture Organization of the United Nations
FGV	Fundação Getúlio Vargas
FTAA	Free Trade Area of the Americas
IEA-SP	Instituto de Economia Agrícola –São Paulo
IPEA	Institute of Applied Economic Research
CONAB	Brazilian National Food Supply Agency
GDP	Gross Domestic Product
IBGE	Brazilian Institute of Geography and Statistics

MDS	Brazilian Ministry of Social Development
MAPA	Ministry of Agriculture, Livestock and Food Supply
MDA	Ministry of Agrarian Development
OECD	Organisation for Economic Co-operation and Development
PDF	Probability Density Function
PND	National Development Plan
PRONAF	National Program for the Strengthening of Family Farming
RFS	Renewable Fuel Standard
SCC	Somatic Cells Count
SELIC	Brazilian Special Clearance and Escrow System
SMP	Skim Milk Powder
SNF	Solids-Nonfat
SNCR	National Rural Credit System
TBC	Total Bacterial Count
TPP	Total Physical Product
UHT	Ultra-High Temperature
WMP	Whole Milk Powder

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CHAPTER I

INTRODUCTION

Studies related to market analysis have played an important role in understanding price dynamics, supply, and demand behavior. Those studies have assisted policy makers and the dairy industry in terms of strategic decisions regarding investments and policies. In Brazil, the dairy sector is an important segment of the agribusiness. From the supply side, Brazil is the fourth largest producer in the world according to the Food and Agriculture Organization (FAO, 2014), and the whole sector is composed of nearly 1.3 million farmers. From the demand side, dairy products account for approximately 11.5% of household expenditure for food (IBGE, 2010). Therefore, Brazilian's families are relatively more sensitive to changes in dairy prices than in other types of food. The sector also generates around US$ 66.7 billion per year, and it is one of the most important segments of the food industry, according to Cônsoli and Neves (2006).

The Brazilian dairy sector has changed significantly over time. Until the early 1990s, a price controlling policy by the Brazilian federal government was in place. Government regulations were not favorable to the development of the local dairy sector because price instability caused reluctance for investment at the farm level. Therefore, during the regulation period a low production per cow, small production per farm, inferior milk quality, and high production costs were observed. However, most of these problems are still in place, thus inhibiting the local industry to become more internationally competitive (Rodrigues, 1999). As a consequence of those factors, there has been a sudden decrease in the number of operating dairy farms. In 1996, around 1.8 million dairy farms were in operation compared to 1.3 million in 2006 (IBGE, 2009). In other words, approximately 50,000 dairy farms went out of business every year over the ten-year period. Nevertheless, both the total milk production and the number of dairy cows increased, suggesting that production per farm is now higher than before.

Another observable characteristic on the supply side is the uncounted mergers and acquisitions among processors. The consolidation was more notable after 2007 when the National Bank of Social Development (BNDES), a Brazilian federal banking agency, became a partner of the dairy firms. Despite the recent market concentration among processors, the Brazilian dairy industry is still very fragmented.

The dairy sector is one of the most complex segments of the agribusiness. The raw milk flows to a bundle of products that uses different transformation methods, packages and inputs. At the farm level, the complexity of managing dairy farms is also increasing due to recent policies like biofuel promotion around the world and the impact on feed cost, land price, among others. Such policies have different drivers depending on each country where the policy is implemented. The dairy farms are sensitive to changes in corn price (and corn-based feed prices) because those inputs account for the majority of grain-based diets in the farm. Trade policies and agricultural policies, such as rural credit and price support, also affect the dairy industry, since those policies have direct impacts on net revenue. Therefore, the future of the dairy sector depends also on how these policies are managed over time.

An econometric model that attempts to replicate the dairy sector in Brazil, and capture important decision points, is developed in this study. Understanding how milk flows from raw materials to the final products, and how the supply curve responds to price and cost changes, will provide insights of impacts for future dairy policies and social planning. A system of equations is built to simulate how well the entire system represents the sector over a historical period. This model may be useful for analyzing internal reactions to exogenous shocks from the supply side, the demand side and public policies. Major variables that likely have a profound effect on the entire industry are be identified as well as those with very low impacts, which may help policymakers to outline a more oriented agenda to develop this industry. Therefore, policymakers and the dairy industry will both benefit from the research.

The dissertation is organized into seven chapters including the introduction. In chapter II, a literature review considers structural econometric models, history of the Brazilian economy, dairy sector in Brazil, and some dairy policies. The chapter III offers details about the model developed in the research, which include methodology, data description and sources, and the main set of equations that is estimated. The chapter IV aims to present forecasts based on the *status quo* of dairy policies and other exogenous shocks. A 10-year forecasts ending in 2022 are analyzed. In the chapter V, alternative scenarios are considered to contrast with the baseline forecast. The chapter VI has the stochastic model as a core, and risk is incorporated into the study. Finally, the conclusion is presented in chapter VII.

1.1. Objective of the Research

The main objective of the research is to develop a structural econometric model to characterize the dairy sector in Brazil that attempts to analyze economic consequences of exogenous shocks and policy changes in the Brazilian dairy sector. As for specific interest, the research will evaluate impacts on the dairy sector to changes in: GDP, subsidized interest rate, milk price support, RFS requirement in the US, and sugar cane acreage in Brazil. A stochastic version of the model will complete the main objectives.

CHAPTER II

LITERATURE REVIEW AND OVERVIEW OF BRAZILIAN DAIRY SECTOR

2.1. Brazilian Macroeconomics

The main goal of this section is to provide a brief overview of macroeconomic aspects of the Brazilian economy in recent decades. The Brazilian economy has gone through many transformations. These include debt crises in the early-1980s, hyperinflation, many tentative stabilization plans, and frequent changes in currency. In the mid-1990s *Plano Real* was implemented, and it succeeded at keeping the inflation rate under control. The late-1990s were also a challenging period with economic crises in Asian countries, Mexico, and Russia, all of which affected the Brazilian economy. In the early and mid-2000s, a better economic environment was established. On the political side, transformations took place over the past five decades. Brazil was ruled under a military dictatorship from 1964 to 1985. During the mid-1980s, a democratic president assumed the government under the fragile economic situation.

After a period of high industrial growth, Brazil faced severe economic difficulties in the 1960s. An intractable inflation rate and massive international debt payments were in place. As pointed out by Markoff (1990), political conflicts linked to the economic situation had become acute. In addition, the oil shock of 1973 quadrupled the price of petroleum. At that time, Brazil was importing around 80% of its oil consumption. The total import bill rose fast reaching US$12.6 billion in 1974 compared to US$ 6.2 billion in 1973 (Baer, 2008).

The policy response came in 1975 with the Second National Development Plan (PND II, 1974-1979) focusing on import substitutions and a fast expansion of infrastructure in general. However, the growth option and the investment program ended dramatically by increasing the international debt for the public sector. Moreover, the second oil shock in 1979 contributed to a decline in the terms of trade and made the economic situation more complicated. At that time, the last military president took office with a political program to restore Brazil to a democracy. In December 1979, a package of measures was adopted that included currency devaluation and tax incentives, among others. The government's price control of activities was increased to avoid inflationary pressures, but the inflation rate was rising fast as well as the external debt.

To complicate matters, in 1982 Mexico declared a debt moratorium and therefore, postponed payments to creditors. This action sent a negative signal to the market players and closed international finance markets to Latin America. As a consequence, Brazil had no option but asked for financial support from the International Monetary Fund (IMF). Simultaneously, the country was trying to roll over its own debt. Many adjustments were suggested and implemented, but a recession period from 1981-1983 was unavoidable. At the time, the inflation rate was running above 100% a year (Baer, 2008). From the political side, the dominant sectors of the military were engaged in democratic restoration. In 1985, Brazil experienced the re-democratization process. A civil government assumed the presidency after a military regime had ruled the country from 1964 to 1985.

A common characteristic of the late-1980s was the many attempts to control inflation, which had been an extremely difficult problem since the 1970s (Amann and Baer, 2000). The many inflation stabilization plans included Cruzado (March/1986), Cruzado II (November/1986), Bresser (1987), Feijão com Arroz (1988), Verão (1989), and Collor (1990). None of these, however, achieved the goal of controlling inflation. While inflation as well as fiscal adjustment were still the focus of these economic plans, in 1990 the government began a process of gradually decreasing trade tariffs.

Meanwhile, in 1992 President Collor was impeached due to corruption and undesirable economic policy decisions. The vice president, Itamar Franco, took over as interim, and in 1993 he named Fernando Henrique Cardoso as his finance minister. At that time, a successful economic plan for containing inflation began to be prepared with the help of a number of economists (Baer, 2008). The plan was later called *Plano Real*. In 1994, *Plano Real* established the basis for long-term stability and growth to reduce Brazil's extreme socioeconomic imbalances. The inflation was brought down from a monthly rate of 47.4% in June 1994 to 1.53% in September of the same year. The plan also had an effect on Gross Domestic Product (GDP). The GDP growth rate reached 5.3% in 1994 and an average of 3% during the next three years. The fiscal problems remained, and the government started a large privatization program to control the debt.

As for international trade, a rapid increase of imports was observed mainly due to the opening of the economy and a stronger exchange rate. Given the strong international competition, both domestic and international firms present in Brazil at that time made an effort to upgrade their technology. They did so by purchasing capital goods overseas to modernize domestic industry. In addition, by reducing inflation, it seemed that the real income of lower income people increased substantially as did their purchasing power. Overall, the *Plano Real* seemed to perform well at the beginning, even considering international economic instability in Mexico (1994-1995), Asia (1997), and Russia (1998).

In 2003, a former trade union leader, Luiz Inacio Lula da Silva, won the presidential election. He took office in January 2003. He was from Brazil's workers Party, and a huge change in terms of governance was expected. People were clueless of how he would manage inflation rate and fiscal responsibility, along with the expansion in social programs and welfare. However, in general his decisions were a manner of caution implementing similar policies that were in place during the previous governors, which helped him build a reputation of economic prudence. The macroeconomic performance under his first government was impressive with GDP growing more than 5% in 2004. Other important factors that contributed to the economic growth after the first year of Lula's presidency were: more extensive utilization of existing capacity; growth in capital formation; growth in consumption; and international demand for commodities which increased exports (Baer, 2008).

Family income also increased as a result of better industrial wages and the rise of the minimum wage. Moreover, the lower income families had an expansion of a conditional cash transfer program (CCT) called *Bolsa Família*. *Bolsa Família* was created in 2003 by integrating previously developed CCT programs (*Bolsa Escola, Bolsa Alimentação, Auxílio Gás,* and *Cartão Alimentação*) into one unified program, and it reached approximately 14 million households according to the Brazilian Ministry of Social Development (MDS, 2013).

Overall, the 2000s were relatively favorable for the Brazilian economy. Brazil underwent improvements in trade balance, per capita income, and expansion of social programs. As a consequence, food consumption as well as dairy consumption increased substantially.

2.2. Policy and Trade

Agricultural policy in Brazil is primarily conducted by two ministries: the Ministry of Agriculture, Livestock and Food Supply (MAPA) and the Ministry of Agrarian Development (MDA). While MAPA deals with commercial agriculture, MDA deals with small-scale family farms. Overall, Brazil's agricultural policy can be described by three main mechanisms: minimum price guarantees, rural credit, and agricultural insurance (practically non-existent).

In regard to dairy policy, the rural credit is the most prominent policy instrument, and it consists of providing financial support with subsidized interest. Financial support goes to both commercial farms and small-scale family farms. For the commercial farms, the National Rural Credit System (SNCR) provides funding to commercialization, cash flow, and investment. In 2012, commercial dairy farms received about US$1.54 billion. For small family farms, a program called PRONAF was built to manage the offers of credit and other agricultural policies. This program, which was created in 1996, was designed to support small farmers by offering them special financial provisions, such as low interest rates. In 2012, about US$1.64 billion was applied to the dairy sector through PRONAF, with interest rate varying from 0.7% to 2.5% a year, according to data from National Rural Credit System (SNCR). As for the minimum price, the basic process of providing market price support consists of regionally announced minimum guaranteed prices by the Secretary of Agricultural Policy.

In regard to trade policy, in 1991 Brazil established an economic and political agreement along with Argentina, Paraguay, and Uruguay. This agreement was called Mercosul. In 2005, Venezuela joined the group. The idea of Mercosul was to encourage trade among the country members. The majority of agricultural imports from Mercosul countries enter duty free. Moreover, a fixed common external tariff (CET) was defined, and it is usually designed to end re-exportation and inhibit imports from countries outside the agreement. In 2012, the CET for dairy products was in the range of 0% to 28%, depending on each individual product.

Brazil is historically a net importer of dairy products, and three main periods of high dairy trade can be observed in the last three decades. From 1980 to 2006, Brazil was a net importer with huge volumes in 1986, and 1994 to 1996. In these periods, a relatively higher income expansion was observed because of economic stabilization plans and inflation control (Martins, 2004). In 2007 and 2008, a positive trade balance was reached due to high international prices. However, after 2009, a net import dairy trade was registered again.

2.3. Brazilian Dairy Sector

The Brazilian dairy sector has changed significantly over time. Regulation of the dairy sector in Brazil started in 1945. At that time, the Federal government had strong interventions over the price of some essential goods, including dairy products. The main purpose of the price intervention policy was to control prices in order to maintain the purchasing power of the Brazilian families. Since dairy products have a relatively high weight on household expenditure, as pointed out by Martins (2004), those prices were subject to strong intervention. However, the regulation experience did not contribute to technology improvements, and thus the development of the dairy sector. In fact, milk price policies, along with a closed economy, delayed investments in the dairy industry.

Since the regulation goal was to keep milk prices at a low level, it did not provide incentives to adopt new technology and management processes. In addition, milk imports, stimulated by government policy, caused price instability in some periods due to the excess of supply. In the 1980s, the total milk production increased, on average, 2.3% per year. In the 1990s, the milk production grew at the rate of 2.5% a year, reaching 3.0% a year in the 2000s (OECD/FAO, 2011). Therefore, a more dynamic growth rate was observed in the post regulation period.

Deregulation of the dairy market occurred from 1989 to 1993. Before that, most of the main milk processing firms were very influential cooperatives. The liberalization brought more price competition between processors, and many cooperatives had financial problems and went out of business (Farina, 2002). The market share of the dairy cooperatives in terms of milk intake declined from around 60% in the early-1990s to less than 40% in the 2000s (Costa, et al., 2004).

At the same time, it was in place both the economic stabilization provided by the *Plano Real*, with positive impacts on income, and the Mercosul treaty, to promote regional trade. Multinational companies also arrived in Brazil, which made the competition between dairy companies and cooperatives even greater. A new set of strategies, such as product differentiation and market segmentation, became more common. From 1993 to 2000, the consumer price of dairy products dropped by 32%. Moreover, the introduction of the Ultra-high temperature processing (UHT milk) in the late-1980s broke regional barriers, since the UHT milk could be transported long distances. The share of the UHT milk on fluid market sales rose from 4.4% in 1990 to 68.8% in 2000 and reached 78.2% in 2011. Finally, dairy consumption was stimulated right after the *Plano Real*, which kept inflation under control and increased the purchasing power of households.

Therefore, the deregulation process increased the competition and opened opportunities to adopt technologies and management strategies. Some examples of transformation that are still in place are cited by Carvalho (2010); that is, milk transport in more appropriate trucks, payment based on milk solids, gain of scale (farm and wholesale level), and international trade ambitions. In fact, when pre and post deregulation are compared, an important distinction is observed. In the former period, the focus was on the production cost, which was used by the government as a parameter to set farm price. In the latter period, however, the focus switched to the consumer as a reference for new investments in technology and products (Martins, 2004).

In 2002, the Brazilian Ministry of Agriculture, Livestock and Food Supply put in place the Normative Instruction 51 that established a minimum parameter of milk transportation, hygiene, and other issues related to milk quality. At that time, a schedule was defined such that all agents involved in the dairy sector would have time to adjust to new rules. Payment per quality has been adopted by some milk processors and it stimulated investments at the farm level. However, milk quality is still very low compared with other countries like New Zealand, the United States of America, and the United Kingdom. The main difference was found in total bacterial count (TBC) where the numbers from Brazil showed to be 16 times higher than New Zealand and 11 times higher than the US (Carvalho, 2010).

Another thing that should be mentioned is related to changes in milk supply across states and regions. In 1980, 51% of milk production was in the Southeast region, 23% South, 14% Northeast, 11% Center-West, and 1% North. However, in 2012 the share of Southeast decreased to 36%, while the South increased to around 33%. Center-West also increased its share of milk supply to almost 15%.

The milk production increased in basically all states, except *São Paulo*, located in the Southeast. *Goiás*, located in Center-West, increased the supply very fast, and it accounts for the majority of the production in that region. All three Southern states (*Paraná, Santa Catarina* and *Rio Grande do Sul*) have also shown an incredible dynamic for growth. *Minas Gerais*, located in the Southeast, is the major Brazilian supplier. The production in that state is still increasing mainly in places close to the grain production, such as *Triângulo Mineiro* (Hott, et al., 2007).

Overall, the top six states in production account for about 77% of the Brazilian milk supply, and their supply function are analyzed individually in the study. All other states are aggregated into one single group due to data constraints.

2.4. Drivers: Policies and Exogenous Relationship

The dairy sector is one of the most complex sectors in agribusiness and involves many different products across the supply chain. At the farm level, the complexity of managing dairy farms has increased with some recent policies like the biofuel based on grains and oilseeds. Such a policy has different drivers depending on each country. In the United States, for example, new uses for corn were observed after the Renewable Fuel Standard (RFS) program regulations in 2005, which established the renewable fuel volume mandate in the United States. In Brazil, the sugar cane expansion has increased land competition on agricultural fields mainly in *São Paulo* state, which hold most of the sugar cane acreage and ethanol industry. In the European Union (E.U.), the promotion of biodiesel from oilseeds has also expanded demand of inputs used by dairy farms.

In the case of the Brazilian sugar cane expansion, the relationships between the ethanol industry and the dairy industry were studied by Novo, et al. (2010). As the authors mentioned, the sugar and ethanol industry expansion is definitely not new since it started in the early-1970's in *São Paulo* state. However, predominance of relatively small dairy farms contrasts with a strong ethanol industry with dynamic and fast growth.

Moreover, while historically the Ethanol industry has been promoted by a range of public policies, such as tax benefits and mandatory use of blending ethanol and gasoline, public policies for the dairy sector were much less directed toward the development of the sector, and usually have served other interests, such as inflation control (Martins (2004), Novo, et al. (2010)). Novo, et al. (2010) concluded that many dairy farmers in *São Paulo* decided to stop production to sell or rent their land to the sugar cane sector. Increased land prices and high rents offered by the sugar cane/ethanol industry attracted farmers to this new opportunity.

Dumortier, et al. (2009) used a partial equilibrium model to measure the impacts of biofuel policies on food prices. The change in biofuel policies and energy prices leads to changes in corn prices and the prices of other crops that compete with corn for land. Moreover, part of this change in price will be transferred to consumers since it impacts the prices of dairy, livestock, and bakery products. In addition, by increasing corn prices in the US, they found that the soybean acreage in the US will decrease, raising soybean price. A spillover effect will also be expected, increasing corn and soybean acreage in Brazil, Argentina, and other countries. However, some authors do not agree that biofuel production was the major factor driving food price increases in 2007-2008. Mueller, et al. (2011) found that food price increases were a result of high petroleum prices, a weak US dollar, and hedge fund investments.

In terms of impacts of biofuels mandates on livestock, a general equilibrium approach was used by Taheripour, et al. (2011) to study this issue. They suggested that biofuel policies had important implications for the global livestock industry, mainly by raising the cost of feed grains. They also found that growth in the US and E.U. biofuels industries had greater negative impacts on livestock production overseas than in those regions. The biofuel mandates increase the price of pastureland because more pastureland is converted into crop land. Therefore, the changes in the US's Renewable Fuel Standards impacted corn prices and livestock production in the United States and in other places as well (Miljkovic, 2012).

Another issue that should be mentioned is related to price variability. Not only do the level of feed prices impact the livestock and dairy industry, but also the price volatility. This issue was studied by Wright (2011), and he expects a less volatile equilibrium price in the future, on a higher price path than it would be without biofuels. Nevertheless, the possibility of grain prices staying high and volatile was not discarded if the political power of those who favored biofuels policies is still in place.

Martins and Guilhoto (2001) offered an input-output matrix approach to capture the link between the dairy sector in Brazil and the sector that provides inputs to it. Their finding indicated that positive changes on family income can stimulate the dairy agribusinesses. Similarly, Martins (2004) pointed out that trade and macroeconomics policies have strong impacts on the Brazilian dairy industry. On the other hand, policies to keep food prices at low levels have transferred income from the dairy sector to consumers, causing a disincentive to invest in technology. Other studies concluded that, historically, public policies in Brazil have punished the dairy sector (Calegar (2001), Martins and Vieira (2001), Tupy (2001)).

As can be noticed above, a complex mix of decisions, including macroeconomic and microeconomic policies, have impacts on the agricultural sector in general, and on the dairy industry in particular. Moreover, the latter is an important issue for Brazil, given its social and economic importance. Therefore, a dairy model is built in such a way that allows us to measure the effects of important decisions over the whole dairy industry.

Brown (1994) developed an econometric model for the US dairy industry making it possible to discuss and simulate how dairy policy affects the sector and how the sector reacts to exogenous shocks. Castro, et al. (2004) measured the impacts of the Free Trade Area of the Americas (FTAA) and Mercosul-E.U. over a group of agricultural commodities, including dairy. By using a general equilibrium model, they found that the dairy sector in Brazil would benefit under the Mercosul-E.U. free trade agreement.

Alvim (2010) examined the main impacts of free trade agreements considering Mercosul, E. U., U. S., and Canada on the dairy sector in Brazil. He offered a partial equilibrium analysis that considers a multiregional and a multi-product dimension. Three different scenarios were compared: 1) free trade agreements between all countries; 2) free trade between Mercosul and E.U.; 3) and free trade between Mercosul, US, and Canada. In all three scenarios, dairy production in Brazil would increase. The most favorable scenario assumes a free trade agreement between Mercosul and E.U., where excess supply in Argentina and Uruguay would be exported to the E.U.. The least favorable option would be the Mercosul, US and Canada in which the growth in milk production in South America Countries will be lower than it would be under the other scenarios.

Overall, there are many studies related to the Brazilian dairy industry. However, none of the studies have performed an analysis that explores structural equations to study the interactions between supply and demand and to replicate the sector over the historical period. Moreover, most of studies have used partial and general equilibrium models to analyze international trade, while little research has been conducted to model dairy in such a way that can be used to evaluate changes in domestic policies, input prices, and income among other variables.

CHAPTER III

BRAZILIAN DAIRY MODEL: DEVELOPMENT AND VALIDATION

3.1. Proposed Methodology

The entire model consists of a partial equilibrium approach to estimate structural supply and demand functions for the Brazilian dairy sector to characterize this sector. Policy changes and pre-determined variables were introduced into the model to evaluate and quantify their impacts. It is important to say that all the equations were based on economic relationships between variables. Additional dummy variables were introduced to correct structural breaks, and to deal with outliers.

As for the structural procedure, a non-linear optimization method was used for the partial equilibrium model, which solved for four different dairy markets: butter, cheese, milk powder, and fresh products. The objective of each market is to minimize the squared excess supply in a given year as described in equation 1.

$$Obj.function = Min\, \Sigma_k \,(supply_k - demand_k)^2 \qquad 1$$

where, k = butter, cheese, milk powder, and fresh products.

The method is dynamic and recursive, and each endogenous variable is explicitly followed over time. The entire model is solved sequentially, one period at a time, for the estimation of a 10-year forecast. Moreover, the model will be exercised by running different scenarios with the baseline as the reference scenario. The baseline considers the *status quo* of the exogenous variables and current policies. Alternatives scenarios will be used to contrast with the existing conditions and will be described in detail in chapter V.

In terms of specification, the equations were estimated using least squares criterion following the classical multiple linear regression model as described in Greene (2008). For each equation that contains the lagged dependent variable, the Breusch-Godfrey Lagrange multiplier test was run to test for the presence of serial correlation. This procedure was applied because Greene (2008) shows that in the presence of serial correlation, all coefficients on the right hand side are inconsistent. In all cases, we fail to reject the null hypothesis, that there was no serial correlation at the 10% significance level. Hence, serial correlation was not a problem in the equations with lagged dependent variables set as covariates.

As for the other equations, without lagged dependent variables, the coefficient estimates are consistent but not efficient. Nevertheless, in some equations where inference was intended, the first order serial correlation problem was fixed using the Prais-Winsten estimator described in Prais and Winsten (1954) and Greene (2008). This procedure was important in the demand side of the model, where the price and income elasticities were calculated and inference was useful. Information criteria, such as Schwarz and Akaike information criterion, were used for selection between different specifications as described by Enders (2003).

3.2. Data Description

As for data, different sources were combined due to challenging limitations in organized and complete datasets. There is no single source that provides all dairy information, which challenges the model development.

As for the number of dairy cows and total milk production, data from OECD-FAO and the Bureau of Statistic of Brazil, namely Brazilian Institute of Geography and Statistics (IBGE), were used. Retail price index for dairy products is also published by IBGE. Data about supply and demand of dairy products (cheese, butter, milk powder and fresh dairy), on the other hand, was offered only by OECD-FAO.

In terms of raw milk prices, corn, and soybean prices the *Fundação Getúlio Vargas* (FGV) were the main source. In some cases, those series were merged with more recent data provided by the Center for Advanced Studies on Applied Economics (Cepea), and the *Instituto de Economia Agrícola* (IEA-SP). Cost of milk production and minimum milk prices were given by the National Food Supply Agency (Conab). Finally, macroeconomic data came from different sources, such as IBGE, the Brazilian Central Bank, and the Institute of Applied Economic Research (IPEA).

3.3. Total Milk Supply

The total milk supply is estimated on a state-by-state basis and considers the top six states in the Brazilian milk production. Due to the unavailability of data, the other states are grouped as one single region. Figure 1 presents the spatial distribution of milk production in Brazil. Basically, dairy farms are located throughout the country. Two main points can be noticed in Figure 1. First, the production has consistently increased as the dark color became more visible in 2012. By pointing out that the city limits did not change over time, the production per acreage has increased as well. Second, the total milk production has been growing in both traditional and nontraditional areas with few exceptions. The top six states, highlighted in the map, represented 76.5% of the total milk production in 1980. In 2012, the same states accounted for 77% of the total production. Therefore, the top six states kept the same share of the total milk production despite the weak performance of *São Paulo*, where the share of the total production decreased from 16% to 5% in the same comparison. As cited by Novo, et al. (2010), the expansion of sugar cane acreages played an important role in explaining the reduction in milk production in *São Paulo*.

For model estimation, the milk production is a result of production per cow, multiplied by the number of dairy cows in each year (Figure 2). The number of dairy cows in Brazil is still growing. Therefore, the total milk production has increased considering its two components, number of dairy cows and production per cow. In fact, by taking into account the whole period of the study (1980 to 2012), the total milk production in Brazil increased by 128%, while the number of dairy cows expanded by 76%. Hence, the number of dairy cows was the major milk production driver from the early-1980s to now.

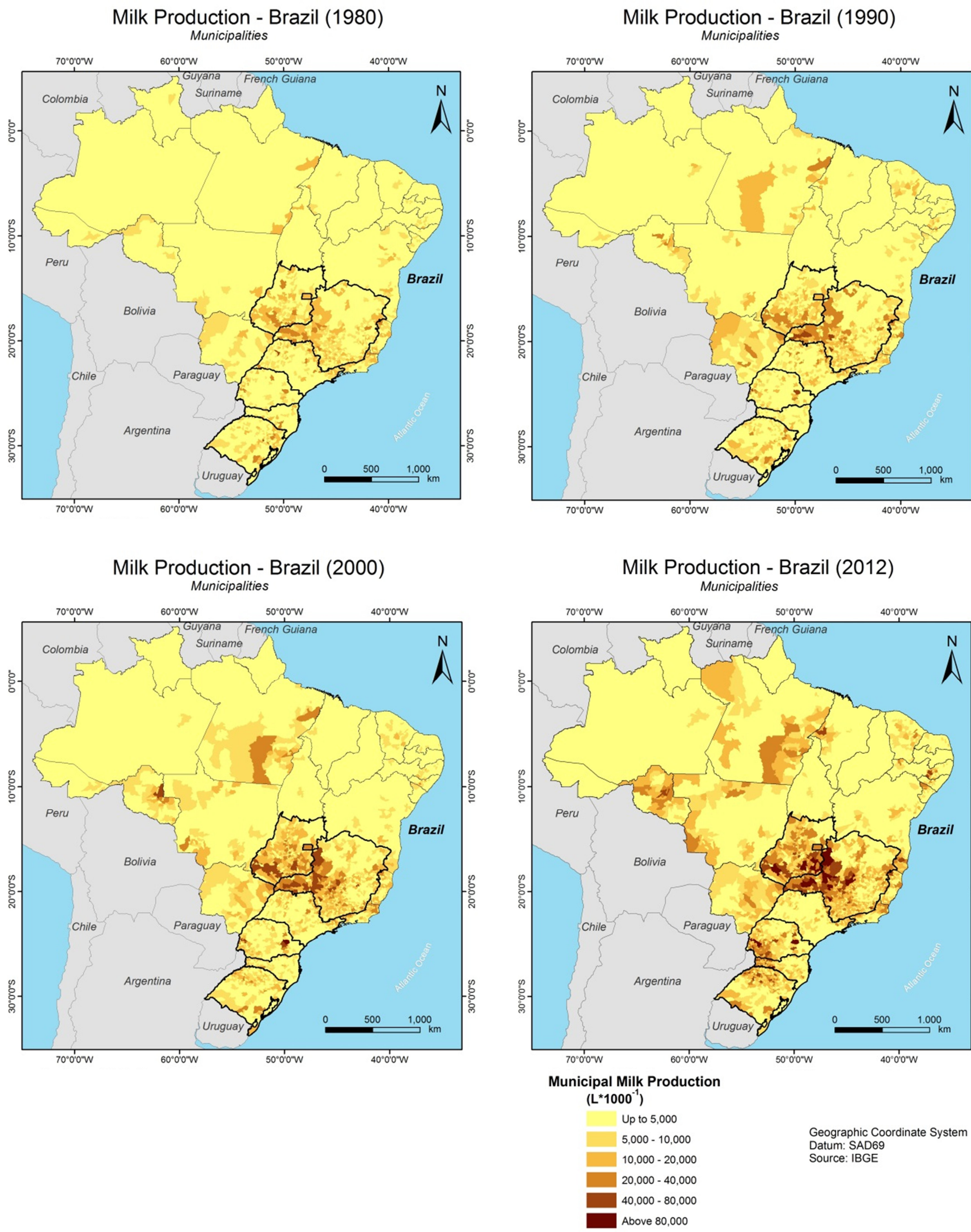

Figure 1. Milk Production in Brazil: 1980 to 2012.

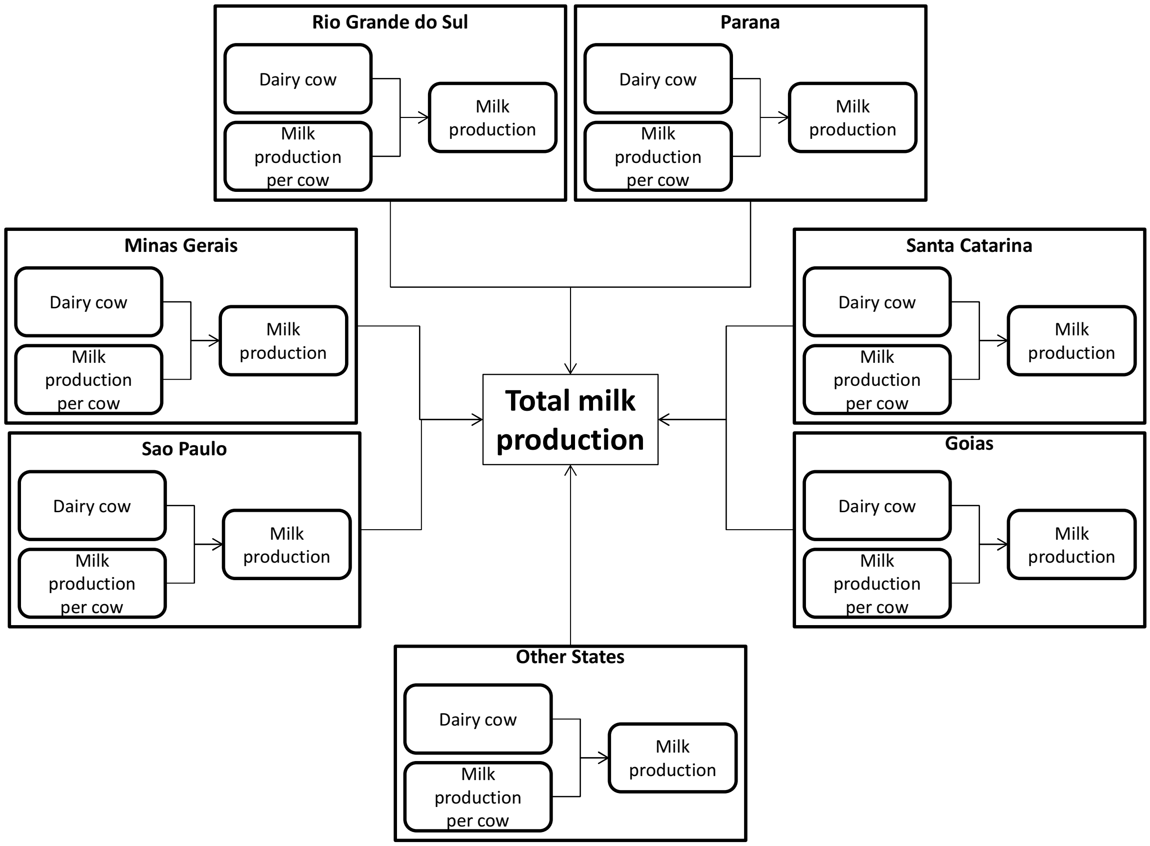

Figure 2. Milk Production Estimation on a State Basis
Note: Adapted from Brown (1994).

As for the conceptual analysis, the simplified diagram represented by Figure 3 provides an overall description of milk price and quantity relationship. Dairy cows on the farm depend upon stock of dairy cows in the previous year and the profitability of producing milk, given the milk price. Milk production per cow is dependent upon time trend, and costs associated with producing milk. The total milk production is determined by the number of dairy cows on the farm and the production per cow. The total supply of milk is an aggregation of each region and represents the entire country.

The manufactured milk price is determined by the interaction between the total milk supply and the different demands for milkfat (and milk solids-nonfat (SNF)). Then, for a given raw milk price, each of the demands for milkfat (milk SNF) depend upon the price of the dairy product, the total milkfat (milk SNF) available, and the cost associated with manufacturing that specific dairy product. In the case of the butter and the SMP production, the prices of both products are important decision points in the industry since they are joint products.

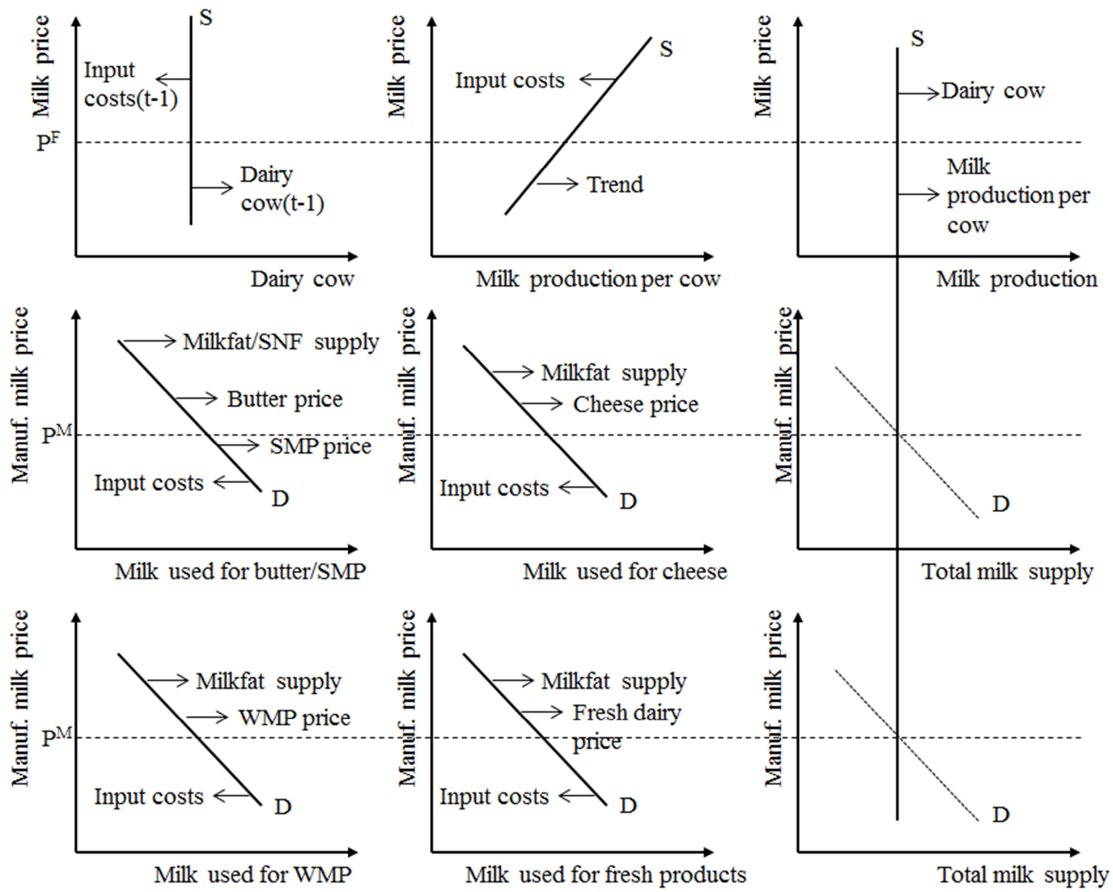

Figure 3. Simplified Diagram of Milk Price and Quantity Relationship.
Note: Adapted from Brown (1994).

As for the empirical model, the equations used to estimate the number of dairy cows are represented in Tables 1 to 7, and these were expressed as a function of dairy cows lagged one year, deflated net revenue lagged one year, and exogenous variables. Following Greene (2008), a Breusch-Godfrey Lagrange multiplier test was run to check for the presence of serial correlation. The results suggested that the null hypothesis of no serial correlation failed to be rejected at the 10% confidence level in all equations.

The lagged dependent variable and the deflated net revenue, as expected, are positively related to number of dairy cows in each state. The latter variable, however, is not statistically significant in any state. The lagged depend variable is included to reflect long-run partial adjustments associated with investment in this industry. Not surprisingly, the states located in the southern Brazil, which have a more homogeneous production system and better management tools, have higher coefficient estimates. The intercept shifter and dummy variables were necessary to account for outliers in the series and/or structural changes. Overall, the exogenous variables have high explanatory power and are statistically significant. In the case of *São Paulo* (Table 3), another variable called sugar cane acreage was also included in the number of dairy cows equation to account for the effect of sugar cane expansion on the dairy sector. The sugar cane acreage in *São Paulo*, as expected, is negatively related to number of dairy cows in that state. Moreover, sugar cane acreage has high explanatory power, and it is significant at the 99% confidence level. In 1980, 49% of the total sugar cane production was located in *São Paulo*. This share sharply increased to 56% in 2012. Figure 4 shows the sugar cane production throughout the country. *São Paulo* has always been the leading state in sugar cane cultivation and the production increased very fast during the 2000s. A spillover effects is also observed in neighboring states, where the expansion of sugar cane was strong as well. However, the inclusion of sugar cane acreage in the number of dairy cow equations in the other states of Brazil did not provide any benefit in terms of goodness of fit.

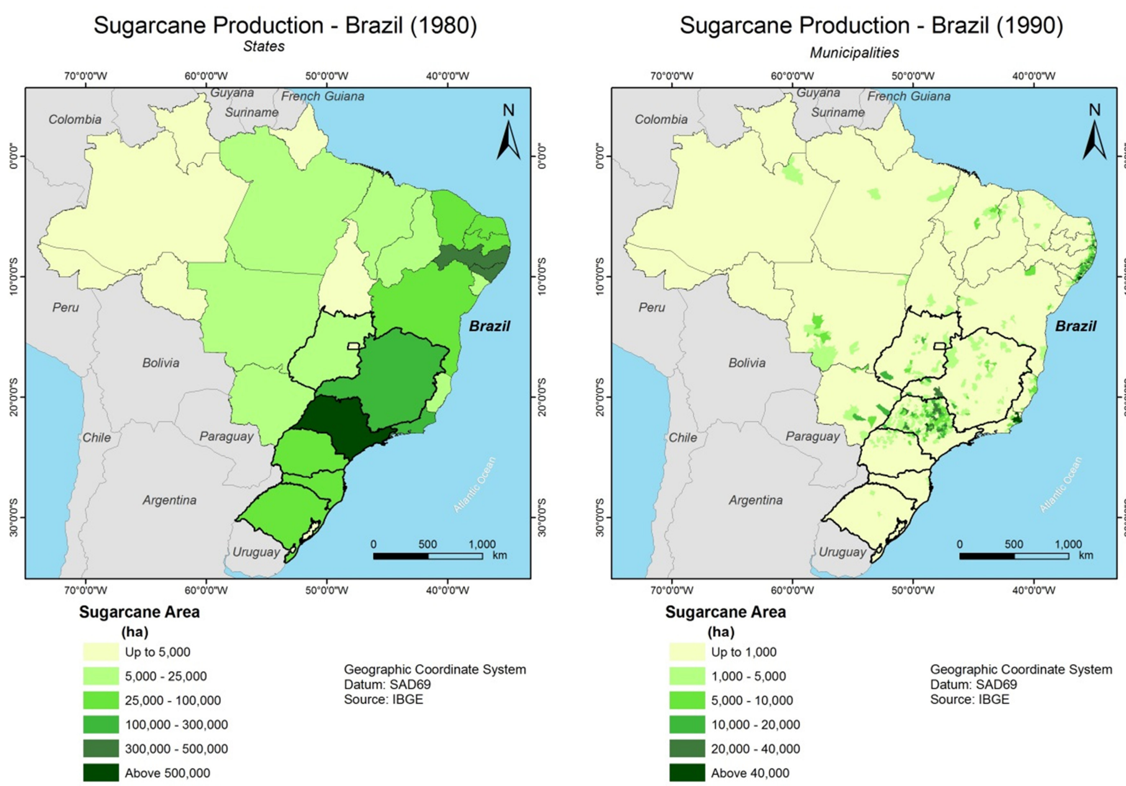

Figure 4. Sugar Cane Production in Brazil: 1980 to 2012

Figure 4. Continued

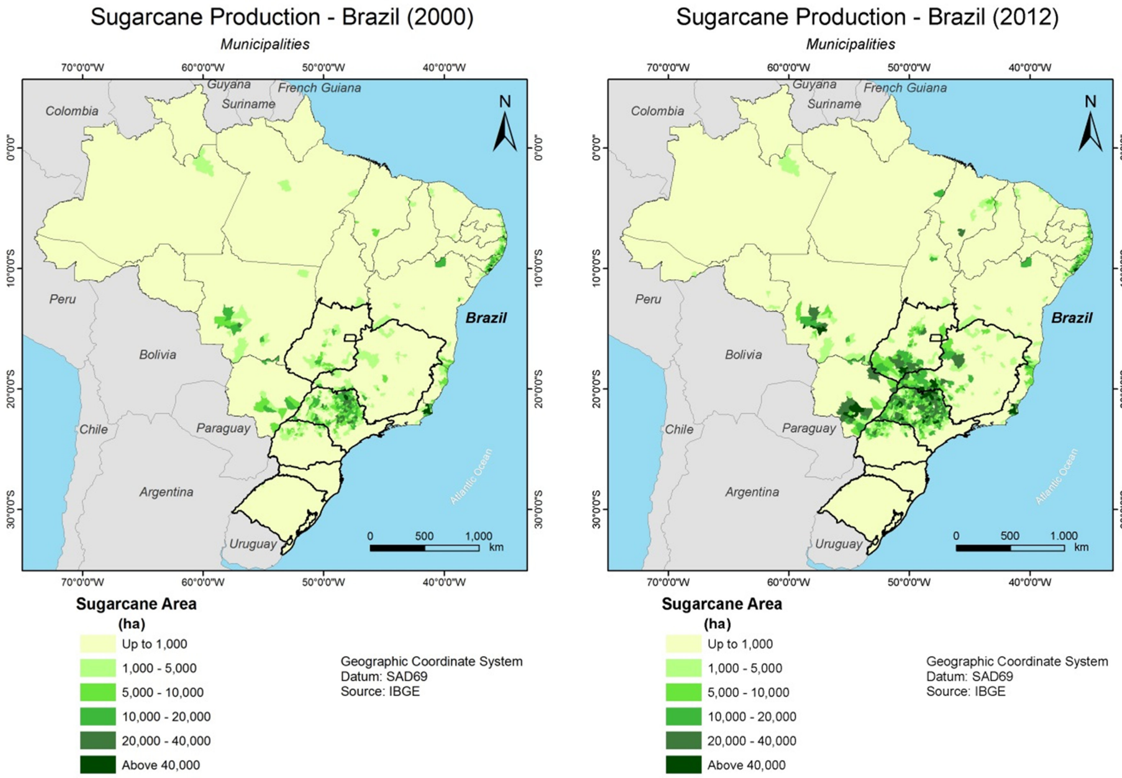

Table 1. Dairy Cow in Goiás

Dependent Variable	Independent Variables	Coefficient	T-statistics
Dairy cow Goiás	Intercept	217.23	1.51
	Dairy cow Goiás (t-1)	0.93	14.01
	Net revenue (t-1)/CPIDEF	39.81	0.85
	D81T82	-359.08	-5.61
	D89	-332.35	-3.97
	D96	-435.63	-5.36

Note: Breusch-Godfrey LM Test P-Value: 0.23 Adj R^2 = 0.9031

Table 2. Dairy Cow in Minas Gerais

Dependent Variable	Independent Variables	Coefficient	T-statistics
Dairy cow Minas Gerais	Intercept	217.76	0.97
	Dairy cow Minas Gerais (t-1)	0.97	18.49
	Net revenue (t-1)/CPIDEF	38.48	0.38
	D80T94	-68.62	-0.87
	D96	-315.58	-3.38
	SHIFT03	88.25	1.54

Note: Breusch-Godfrey LM Test P-Value: 0.32 Adj R^2: 0.9815

Table 3. Dairy Cow in São Paulo

Dependent Variable	Independent Variables	Coefficient	T-statistics
Dairy cow São Paulo	Intercept	757.42	3.80
	Dairy cow São Paulo (t-1)	0.67	7.53
	Net revenue (t-1)/CPIDEF	15.99	0.41
	Sugar cane acreage São Paulo	-0.000073	-4.32
	D80T90	-68.78	-2.62
	D96	213.12	5.45
	SHIFT10	121.95	3.50

Note: Breusch-Godfrey LM Test P-Value: 0.24 Adj R^2: 0.9401

Table 4. Dairy Cow in Paraná

Dependent Variable	Independent Variables	Coefficient	T-statistics
Dairy cow Paraná	Intercept	27.50	0.36
	Dairy cow Paraná (t-1)	0.99	14.27
	Net revenue (t-1)/CPIDEF	8.82	0.31
	D80T84	-39.93	-1.80
	SHIFT03	28.74	1.02

Note: Breusch-Godfrey LM Test P-Value: 0.78 Adj R^2: 0.9819

Table 5. Dairy Cow in Santa Catarina

Dependent Variable	Independent Variables	Coefficient	T-statistics
Dairy cow Santa Catarina	Intercept	12.74	0.42
	Dairy cow Santa Catarina (t-1)	0.99	18.11
	Net revenue (t-1)/CPIDEF	21.40	1.03
	D80T90	-23.28	-1.23
	D05	-24.64	-1.02
	SHIFT04	40.37	2.04

Note: Breusch-Godfrey LM Test P-Value: 0.24 Adj R^2: 0.9889

Table 6. Dairy Cow in Rio Grande do Sul

Dependent Variable	Independent Variables	Coefficient	T-statistics
Dairy cow Rio	Intercept	55.83	0.65
Grande do Sul	Dairy cow Rio Gr. do Sul (t-1)	0.98	14.20
	Net revenue (t-1)/CPIDEF	17.33	0.32
	D80T90	-31.31	-0.70
	D02T03	-40.51	-0.95
	D05	-29.23	-0.51

Note: Breusch-Godfrey LM Test P-Value: 0.73 Adj R^2: 0. 9277

Table 7. Dairy Cow in Other States

Dependent Variable	Independent Variables	Coefficient	T-statistics
Dairy cow Other	Intercept	742.95	2.15
States	Dairy cow Other States (t-1)	0.92	22.07
	Net revenue (t-1)/CPIDEF	239.32	0.81
	D80T94	-433.17	-1.98
	D97	-254.62	-0.96

Note: Breusch-Godfrey LM Test P-Value: 0.28 Adj R^2: 0.9817

Dairy farms in Brazil are very heterogeneous in terms of size, management, and use of technology. There are a mix of farms with professional management and good technical and financial control, contrasting with other farms where the cost of milk production is still unknown. Similarly, in some regions of the country a higher yield per cow is observed, while in other regions the production per cow does not reach 1,000 kg of milk per year. On average, the states located in the South of Brazil have higher levels of production per cow. The output for estimated equations regarding milk production per cow is presented in Tables 8 to 14. The dependent variables were estimated as a function of trend and deflated net revenue, except in *Goiás*, where the trend was replaced by lagged one year production per cow because of serial correlation issues.

The time trend variable represents the effects of technology over time. The net revenue variable, on the other hand, considers the effect of relative profitability of producing milk. Since the average of milk production per cow is low in Brazil, additional input, such as feed, can affect positively the production per dairy cow. In fact, supplementary feed is a common practice in dairy farms whenever the output/input price relationship is favorable.

As for the time trend, the impact of such a variable on the production per cow is higher for the states located in the Southern region compared to the rest. The coefficients are also statistically more significant relative to states in other regions. Moreover, the production per cow in Southern of Brazil is more sensitive to changes in net revenue. Therefore, the production per cow responds best to time trend (technology) and net revenue in the regions where the milk production is more organized and the farms are managed with relatively more professional techniques. Finally, exogenous variables were necessary to account for outliers in the series. Overall, the exogenous variables have a high explanatory power and confidence level.

Table 8. Milk Production per Cow in Goiás

Dependent Variable	Independent Variables	Coefficient	T-statistics
Production per cow	Intercept	19.65	0.39
Goiás	Production per cow (t-1)	0.98	23.68
	Net revenue/CPIDEF	104.32	2.08
	D80T90	-83.34	-3.19
	D82	116.68	3.87
	D96	447.36	13.9

Note: Breusch-Godfrey LM Test P-Value: 0.66 Adj R^2: 0.9912

Table 9. Milk Production per Cow in Minas Gerais

Dependent Variable	Independent Variables	Coefficient	T-statistics
Production per cow	Intercept	1275.89	28.75
Minas Gerais	Net revenue/CPIDEF	13.12	0.24
	Trend	9.29	6.36
	D80T90	-34.82	-1.1
	D95T97	186.84	5.68
	D98T04	92.76	3.86

Note: Durbin-Watson statistic: 2.22 Adj R2 = 0.9141

Table 10. Milk Production per Cow in São Paulo

Dependent Variable	Independent Variables	Coefficient	T-statistics
Production per cow	Intercept	995.77	24.52
São Paulo	Net revenue/CPIDEF	22.47	0.55
	Log(trend)	39.85	3.51
	D80T95	290.32	12.14
	D97T01	107.21	5.12

Note: Durbin-Watson statistic: 1.48 Adj R^2 = 0.9225

Table 11. Milk Production per Cow in Paraná

Dependent Variable	Independent Variables	Coefficient	T-statistics
Production per cow	Intercept	1,245.21	18.38
Paraná	Net revenue/CPIDEF	202.20	3.19
	Trend	33.15	13.72
	D00T06	-121.43	-3.43

Note: Durbin-Watson statistic: 1.52 Adj R^2 = 0.9220

Table 12. Milk Production per Cow in Santa Catarina

Dependent Variable	Independent Variables	Coefficient	T-statistics
Production per cow	Intercept	1,320.00	38.79
Santa Catarina	Net revenue/CPIDEF	76.52	1.66
	Trend	36.41	25.46
	D80T89	166.14	4.08
	D03T04	69.43	1.99

Note: Durbin-Watson statistic: 1.67 Adj R^2 = 0.9730

Table 13. Milk Production per Cow in Rio Grande do Sul

Dependent Variable	Independent Variables	Coefficient	T-statistics
Production per cow	Intercept	1,578.62	31.26
Rio Grande do Sul	Net revenue/CPIDEF	145.69	2.48
	Trend	28.25	14.29
	D80T88	-148.33	-3.22
	D03T06	-176.75	-5.22

Note: Durbin-Watson statistic: 1.88 Adj R^2 = 0.9528

Table 14. Milk Production per Cow in Other States

Dependent Variable	Independent Variables	Coefficient	T-statistics
Production per cow	Intercept	849.26	33.00
Other States	Net revenue/CPIDEF	53.47	2.83
	Log(trend)	7.33	0.88
	D80T89	-39.57	-2.58
	D03T12	-54.81	-6.07

Note: Durbin-Watson statistic: 1.47 Adj $R^2 = 0.6279$

The remaining equations in this section provide estimates of Brazil's dairy cow number, total milk production and production per cow. Given the number of dairy cows calculated per each state, the total dairy cows are added up in equation 2. A similar procedure is used to determine the total milk production described in equation 3. Finally, the equation 4 estimates the average production per cow in Brazil.

$$DYCOF_{Brazil} = DYCOF_{Goiás} + DYCOF_{Minas\ Gerais} + DYCOF_{São\ Paulo} + DYCOF_{Paraná} + DYCOF_{Santa\ Catarina} + DYCOF_{Rio\ Grande\ do\ Sul} + DYCOF_{Other\ states} \quad (2)$$

$$DYMKPRD_{Brazil} = DYMKPRD_{Goiás} + DYMKPRD_{Minas\ Gerais} + DYMKPRD_{São\ Paulo} + DYMKPRD_{Paraná} + DYMKPRD_{Santa\ Catarina} + DYMKPRD_{Rio\ Grande\ do\ Sul} + DYMKPRD_{Other\ states} \quad (3)$$

$$DYMPPC_{Brazil} = DYMKPRD_{Brazil}/DYCOF_{Brazil} \tag{4}$$

3.4. Dairy Products

The dairy industry is one of the most complicated sectors of agribusiness since it involves the manufacture of a wide bundle of products, most of them with short shelf life. The total raw milk supply flows to different dairy products as described in the previous section (Figure 3), and the total supply of each product is defined as the sum of production, imports, and beginning stocks. On the other hand, the total demand is calculated by total consumption, exports, and ending stocks. For both the supply and the demand side of the model, international trade is mostly marginal in the Brazilian dairy sector. Brazil is historically a net importer country, and trade is still not consolidated in the dairy industry. Most of the transactions are sporadic and usually happen to fulfil eventual gaps in the supply or demand.

This chapter aims to develop the structural relationship across variables in each dairy market and to present the main estimated equations. The sign of each parameter estimated has to be consistent with economic theory, and the appropriate sign of each coefficient is relevant for the forecast, which is offered in the next chapter.

As for the conceptual analysis, Figure 5 describes the simplified diagram of dairy production and total consumption (disappearance) in the price/quantity space. The wholesale price is determined by the interaction between the total supply of each product and the demand. However, since the wholesale price is not available in the dataset, it is only theoretically presented in Figure 5 but won't be modeled in the research. The very last graph reflects the domestic demand for dairy products, and the price line is shifted up to represent the retail added value, assuming that the retail price is always set above the wholesale price. The consumption of each dairy product depends upon the price of each good and income.

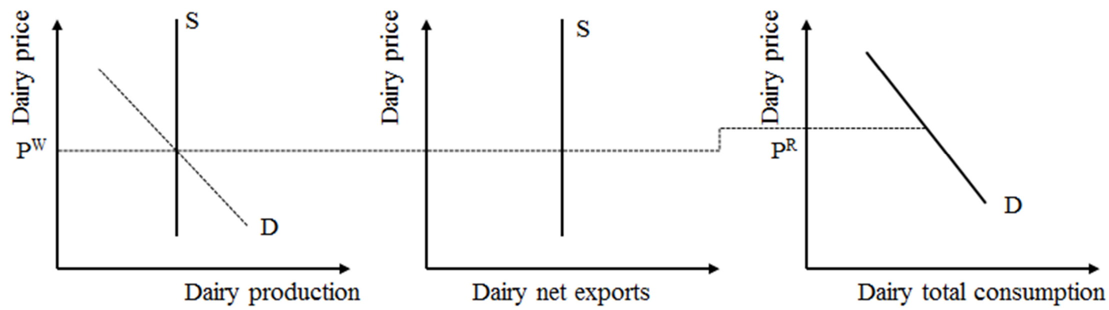

Figure 5. Simplified Diagram of Dairy Products Price and Quantity Relationship.
Note: Adapted from Brown (1994).

3.4.1. Butter Market

The total supply of butter is represented by the sum of beginning stocks, imports, and production, as described in Figure 6.

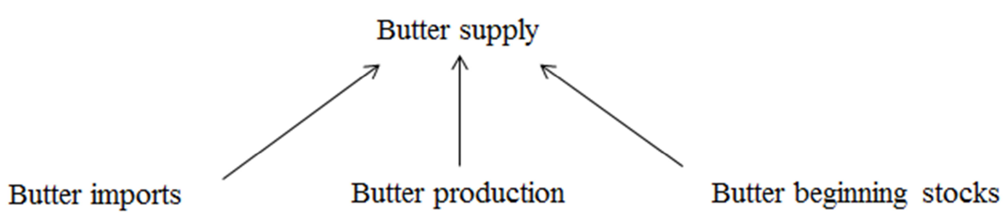

Figure 6. Flow Diagram of Butter Supply

As for butter imports, the amount purchased from another country is not relevant compared to domestic consumption or production. Nevertheless, Brazil holds a historical position of net importer on the butter market. From 1980 to 2012, the average imports of butter represented around 8% of the butter production in the same period. The import of butter in the mid-1990s was relatively more significant than in the other periods. At that time, favorable macroeconomics conditions, caused by *Plano real*, yielded strong increase in consumption. As a result, almost one fifth of the butter supply came from the import component.

Regarding estimates, Table 15 summarizes the results for the butter import equation. The total imports are explained by the import lagged one year and the deflated butter price. Both variables are positively related with butter imports, as expected, and statistically significant at the 98% confidence level. Exogenous variables were also incorporated at the equation due to spikes on the series, most of which representing economic plans like *Cruzado* and *Cruzado II* in 1986, *Collor* in 1990 and *Real* in 1994. The Breusch-Godfrey LM Test was performed to test for the presence of serial correlation. The results yielded a p-value of 0.56, failing to reject the null hypothesis of no serial correlation.

Table 15. Butter Imports

Dependent Variable	Independent Variables	Coefficient	T-statistics
Butter imports	Intercept	-6.47	-1.81
	Butter imports (t-1)	0.32	2.48
	Butter retail price index/CPIDEF	0.09	2.56
	D869095	9.71	4.65
	D0912	3.05	1.21

Note: Breusch-Godfrey LM Test P-Value: 0.56 Adj $R^2 = 0.4895$

The production of butter as well as other dairy products is represented by the amount of milk fat used to produce butter multiplied by the conversion rate (kilograms of milk fat in one kilogram of butter). The conversion rate was based on Torres, et al. (2000) and the LBR-Lacteos Brazil's experts (one of the largest dairy companies in Brazil). The details of the content of each product are summarized in Table A-6 in the Appendix. The simplified flow diagram of butter production is presented in Figure 7.

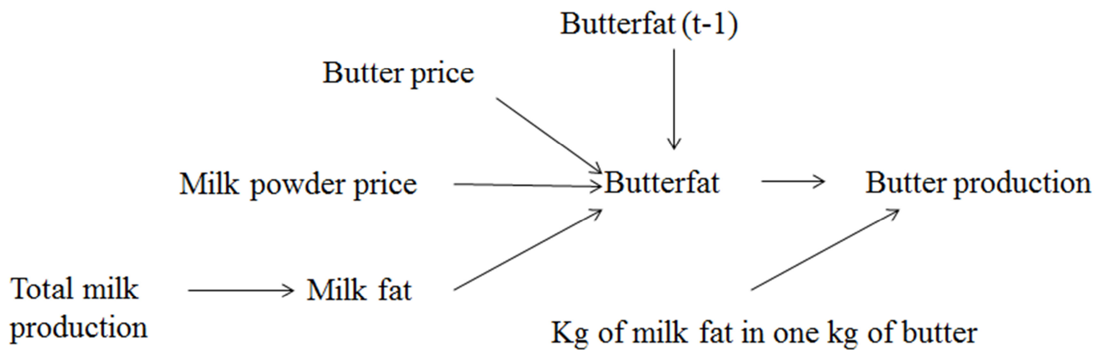

Figure 7. Flow Diagram of Butter Production

As for the estimation, the fitted equation of butter production is expressed as a function of butter production lagged one year, deflated butter price, deflated milk powder price and total milk fat available (Table 16). All coefficients are positively related with butter production, as expected, but only milk fat available and butter production lagged one year are statistically significant at the 90% level. The milk powder price is part of the equation because skim milk powder and butter are joint products; that is, the milk fat left over from the skim milk production is used to make butter. Similarly, the amount of solids-nonfat left over from the butter production is used to make skim milk powder. The Breusch-Godfrey LM test did not suggest the presence of serial correlation at the 10% level.

Table 16. Milkfat used for Butter Production

Dependent Variable	Independent Variables	Coefficient	T-statistics
Milkfat used for	Intercept	2.43	0.27
Butter	Milkfat used for Butter (t-1)	0.46	2.58
	Butter retail price index/CPIDEF	0.08	1.25
	Milk powder price index/CPIDEF	0.02	0.15
	Total milkfat	0.02	2.25
	D93	-15.35	-2.59
	D06T08	3.84	1.33

Note: Breusch-Godfrey LM Test P-Value: 0.24 Adj R^2 = 0.8395

On the other hand, the demand for butter is represented by the sum of ending stocks of butter, exports and domestic consumption, as described in Figure 8. Since Brazil does not have a policy to hold stocks, the ending stocks of butter are close to zero.

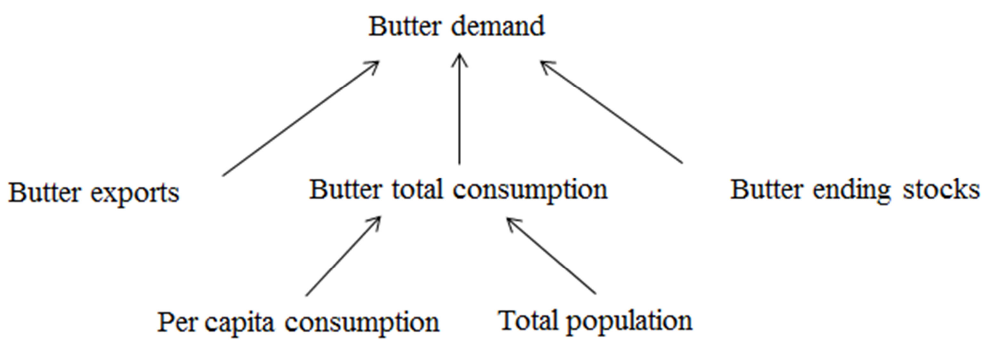

Figure 8. Flow Diagram of Butter Demand

In terms of exports, the quantity of butter sold is also marginal and irregular. Basically, the yearly average of butter exported from 1980 to 2012 was 1,000 metric tons, which represented only 1.6% of the domestic butter production in the same period. The export equation was estimated as a function of exports lagged one year and deflated retail price of butter (Table 17). The former is positively related to butter exports, while the latter has a negative effect on exports, as expected. However, those coefficients are not statistically significant. Exogenous dummy variables were included to account for occasional peaks in butter exports. The Breusch-Godfrey LM Test was run to check for presence of serial correlation and it failed to reject the null hypothesis of no serial correlation at the 10% confidence level.

Table 17. Butter Exports

Dependent Variable	Independent Variables	Coefficient	T-statistics
Butter exports	Intercept	0.93	0.70
	Butter exports (t-1)	0.24	1.39
	Butter retail price index/CPIDEF	-0.01	-0.43
	D81839701	2.54	3.92
	D0811	1.10	1.11

Note: Breusch-Godfrey LM Test P-Value: 0.12 Adj $R^2 = 0.3630$

The last component of the butter demand is represented by the total consumption, which is the product of the per capita consumption and the Brazilian population. The per capita consumption of butter has been steady over the period of analysis. Therefore, the total consumption had increased based on the population growth.

The per capita consumption equation, summarized in Table 18, is presented in logarithm form to allow direct calculation of the own-price and income elasticities. The consumption is negatively related to butter price and positively related with the per capita GDP, as economic theory suggests. Moreover, the per capita consumption is more sensitive to changes in GPD than to variations in butter price. The own-price elasticity of butter is also not significant at the 90% of confidence level. The income elasticity, on the other hand, is significant and inelastic. Exogenous variables were included to correct for periods of relatively high level of consumption, such as in 1986, with *Plano Cruzado,* and right after *Plano Real*, in 1994.

Table 18. Butter per Capita Consumption

Dependent Variable	Independent Variables	Coefficient	T-statistics
Log (Butter per capita consumption)	Intercept	-3.78	-3.16
	log(Butter price index/CPIDEF)	-0.14	-1.67
	log(GDP per capita)	0.36	2.88
	D86	0.19	2.52
	D94t00	0.21	5.97
	D11	-0.09	-1.13

Note: Durbin-Watson statistic: 1.53 Adj R^2 = 0.5591

3.4.2. Cheese Market

The supply of cheese is represented by the sum of beginning stocks, imports, and production, as described in Figure 9. Brazil does not have any policy for holding stocks and therefore, these are close to zero. Imports are also not very strong. Consequently, the main component of the cheese supply is the production.

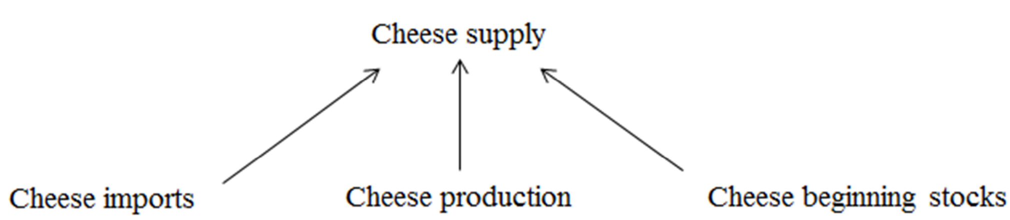

Figure 9. Flow Diagram of Cheese Supply

The cheese imports represented, on average, around 3.5% of the total supply during the 33 years analyzed. By looking into the historical cheese imports, no trend was observed in the time series. However, sporadic peaks in import were noticed, most of which representing periods of relatively high economic growth. A greater volume of imports was observed in the mid-1980s, mid-1990s, and from 2009-2012 period.

The estimated equation for cheese imports is reported in Table 19. Similar to the butter case, the cheese import depends upon imports lagged one year and the deflated cheese retail price. Both coefficients are statistically significant and have positive signs, as expected. Exogenous variables were included in the equation to capture effects of outliers. The intercept shifter intended to replicate a relatively high volume imported after 2009. As for the presence of serial correlation, the Breusch-Godfrey LM Test was performed, and the result suggested no serial correlation in the import equation.

Table 19. Cheese Imports

Dependent Variable	Independent Variables	Coefficient	T-statistics
Cheese imports	Intercept	-28.69	-2.47
	Cheese imports (t-1)	0.67	6.36
	Cheese retail price index/CPIDEF	0.31	2.80
	D869095	24.18	5.20
	D08T10	7.70	1.63
	SHIFT12	2.47	0.30

Note: Breusch-Godfrey LM Test P-Value: 0.33 Adj R^2 = 0.7012

The production of cheese is the most dynamic component of the cheese supply. It has been consistently growing over time. The simplified diagram, described in Figure 10, represents the cheese production.

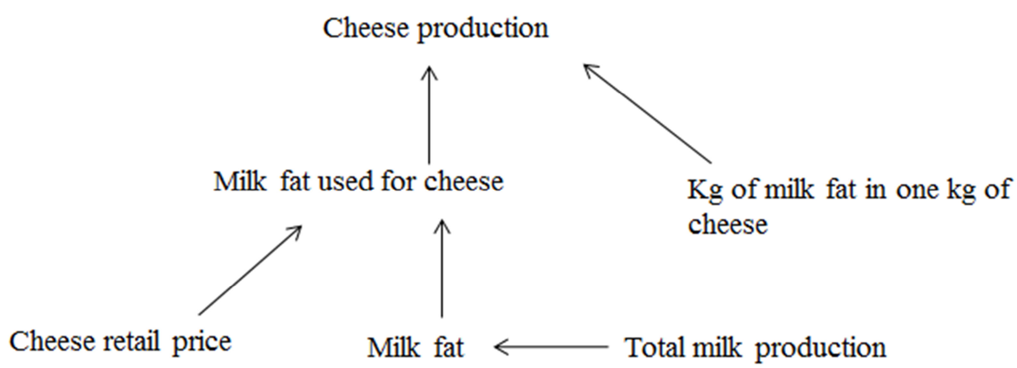

Figure 10. Flow Diagram of Cheese Production

The estimated equation for the amount of milk fat used to produce cheese is reported in Table 20, and depends upon the deflated cheese retail price and the total milk fat available. Both cheese price and milk fat available are positively related to cheese production, but only the latter is statistically significant. Exogenous dummy variables were included in the equation to represent periods of relatively low growth rate. The intercept shift was also incorporated to account for a relatively high expansion in cheese production right after the mid-1990s. Those variables were important for the appropriate relationships of the entire system of equations. They were not statistically significant, though.

Table 20. Milkfat used for Cheese Production

Dependent Variable	Independent Variables	Coefficient	T-statistics
Milkfat used for	Intercept	-61.94	-2.75
Cheese	Cheese retail price index/CPIDEF	0.12	1.19
	Total milkfat	0.19	10.04
	D80T90	2.42	0.31
	D91T92	5.64	0.96
	SHIFT95	7.52	1.27

Note: Durbin-Watson statistic: 1.65 Adj R^2 = 0.8409

The cheese demand has three main components: exports, total consumption and ending stocks. The exports of cheese are not that strong, while the total domestic consumption is the main component of the demand side, which is summarized in Figure 11. The ending stocks are close to zero and do not play any important rule in the cheese market in Brazil.

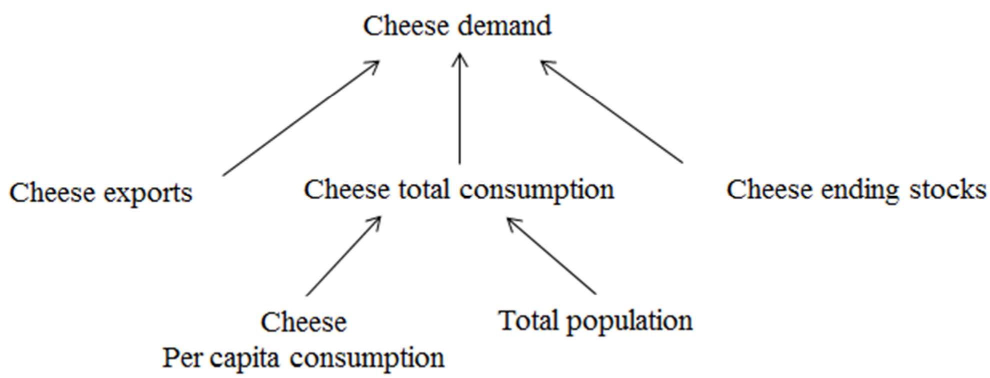

Figure 11. Flow Diagram of Cheese Demand

The amount of cheese exported from Brazil represents an irregular component of the cheese demand. The country is historically a net importer, and only in the late 2000s has the export volume significantly risen. Shipments of cheese usually occur sporadically rather than being a regular component of the demand side. From 1980 to 2012, the average cheese exported represented less than 1% of the domestic production.

The export equation for cheese is estimated as a function of the export lagged one year, the deflated cheese retail price, and the exchange rate measured in *Reais* per US Dollar (Table 21). The cheese price coefficient is negatively related to exports, as expected. It is not statistically significant, though. However, both the cheese export lagged one year and the exchange rate are significant and positively related to cheese exports at current time. Exogenous variables were also included in the equation to capture time period with exports close to zero (during the 1980s) and peak in exports (2005 to 2006). Serial correlation is not a problem in the cheese export equation as indicated by the Breusch-Godfrey LM Test.

Table 21. Cheese Exports

Dependent Variable	Independent Variables	Coefficient	T-statistics
Cheese exports	Intercept	-0.71	-0.31
	Cheese exports (t-1)	0.73	7.00
	Cheese retail price index/CPIDEF	-0.0006	-0.03
	Exchange rate	0.75	1.97
	D80T90	-0.32	-0.58
	D05T06	1.98	1.86

Note: Breusch-Godfrey LM Test P-Value: 0.26 Adj R^2 = 0.8404

The last component of the demand for cheese is the domestic consumption, which is a product of per capita consumption and total population. The per capita consumption has increased firmly during the whole period of the study, reaching almost 4.0 kg per people in 2012 (over about 1.5 kg in the early-1980s), for a growth rate around 3% per year during the study period. The per capita consumption was estimated depending upon cheese price, retail butter price and per capita GDP, all in logarithm as reported in Table 22. The cheese price, as expected, is negatively related to cheese consumption, while butter price and GDP are positively related. Hence, butter enters as a substitute for cheese. Moreover, both butter price and GDP per capita are statistically significant. The income elasticity is relatively high (at 0.88), regardless of inelasticity. It means that cheese consumption in Brazil is comparatively more sensitive to income than other dairy products. Similar results were found by Hoffmann (2000). A positive trend variable and other exogenous variables were also included in the estimated equation, all of those strongly significant.

Table 22. Cheese per Capita Consumption

Dependent Variable	Independent Variables	Coefficient	T-statistics
Log (Cheese per capita consumption)	Intercept	-7.65	-4.53
	log(GDP per capita)	0.88	4.90
	log(Cheese price index/CPIDEF)	-0.22	-1.87
	log(Butter price index/CPIDEF)	0.19	2.36
	Trend	0.01	3.26
	D80T84	-0.15	-4.99
	D89T93	-0.08	-3.01
	D04T06	-0.10	-3.48

Note: Durbin-Watson statistic: 1.39 Adj $R^2 = 0.9685$

3.4.3. Milk Powder Market

The supply side of the milk powder market is composed of imports, production and ending stocks. In terms of procedure, the production was estimated for both the skim milk powder (SMP) and the whole milk powder (WMP). Imports and beginning stocks, on the other hand, were computed in aggregate because of data constraints.

The beginning stocks of milk powder are close to zero and the equation is omitted for simplicity. Imports and production, however, are described in more detail. The simplified supply diagram for milk powder market is presented in Figure 12.

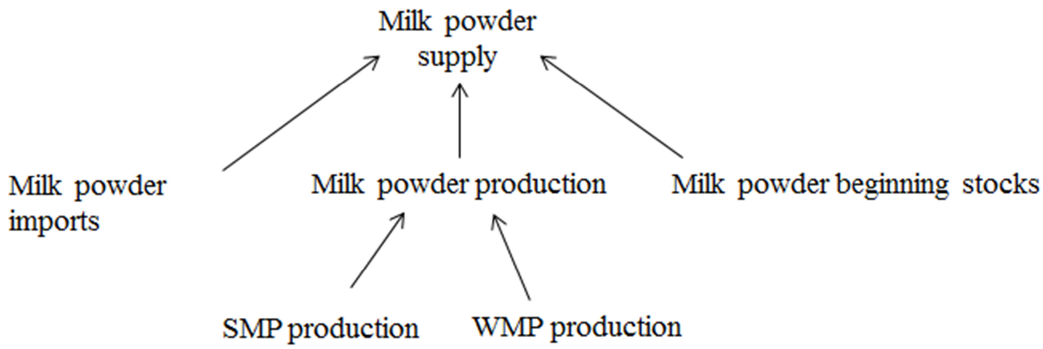

Figure 12. Flow Diagram of Milk Powder Supply

In terms of international trade, the milk powder import and export are relatively more developed than the other dairy products in Brazil. On average, the total milk powder imported represented almost one fourth of the total production during the period of the study, from 1980 to 2012. Nevertheless, the volume imported fluctuated considerably over time. In other words, the imports was not consistent as a regular component of the milk powder supply. Occasional imports were always the case.

As for estimation, the imports of milk powder depend on imports lagged one year and milk powder domestic price (Table 23). The coefficient estimates are both positive, as expected. However, only the lagged dependent variable is statistically significant. Exogenous variables were incorporated in the equation to correct for outliers in the data. The Breusch-Godfrey LM Test suggested that serial correlation is not present in the import equation.

Table 23. Milk Powder Imports

Dependent Variable	Independent Variables	Coefficient	T-statistics
Milk powder imports	Intercept	17.22	0.24
	Milk powder imports (t-1)	0.43	2.96
	Milk powder price index/CPIDEF	0.27	0.36
	D869095	109.61	3.31
	D80T85	-24.47	-0.93

Note: Breusch-Godfrey LM Test P-Value: 0.17 Adj R^2 = 0.4213

As for the production, milk powder was estimated in terms of solids-nonfat content. Moreover, SMP and WMP were fitted in two separate equations. It is worth remembering that WMP is the main milk powder produced in Brazil and it represents around 80% of total production.

The simplified diagram of SMP production is described in Figure 13. The SMP equation was estimated as a function of solids-nonfat used for SMP lagged one year, deflated milk powder price at the retail level, butter production and total solids-nonfat available (Table 24). All coefficients are positively related with solids-nonfat used to produce SMP, but only butter production is significant at the 90% confidence level. As pointed out before, butter and SMP are joint products and SMP production has a close relationship with butter production. Dummy variables were included to account for outliers, while the intercept shifter corrects for higher levels of production since 2002. The Breusch-Godfrey test for serial correlation was performed and the null hypothesis of no serial correlation failed to be rejected at the 90% confidence level.

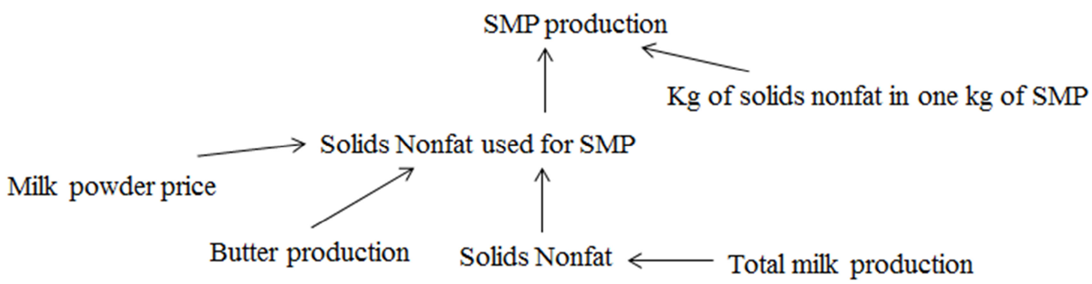

Figure 13. Flow diagram of SMP production

Table 24. Solids Nonfat used for Skim Milk Powder Production

Dependent Variable	Independent Variables	Coefficient	T-statistics
Solids-nonfat used	Intercept	-23.64	-1.70
for SMP	Solids-nonfat used for SMP (t-1)	0.40	1.84
	Milk powder price index/CPIDEF	0.01	0.04
	Butter production	0.73	2.99
	Total solids-nonfat	0.01	0.64
	D828693	-9.71	-1.78
	SHIFT02	21.40	1.94

Note: Breusch-Godfrey LM Test P-Value: 0.34 Adj R^2 = 0.9554

As for the WMP production, the simplified diagram is presented in Figure 14. It is similar to the SMP diagram with the butter production variable removed. Therefore, the WMP production depends on solids-nonfat used for WMP lagged one year, milk powder price, and total solids-nonfat available. Most of the variation in the WMP production is explained by the solids-nonfat used for WMP one year before. A dummy variable representing the period from 1980 to 2000 was included to address a higher growth rate of WMP production after 2000. Another dummy variable, included in 2009, accounts for the sudden drop in WMP production. Both exogenous variables are highly significant. Since the lagged dependent variable is present on the right hand side of the equation, a test for serial correlation was performed. The Breusch-Godfrey LM test did not find serial correlation.

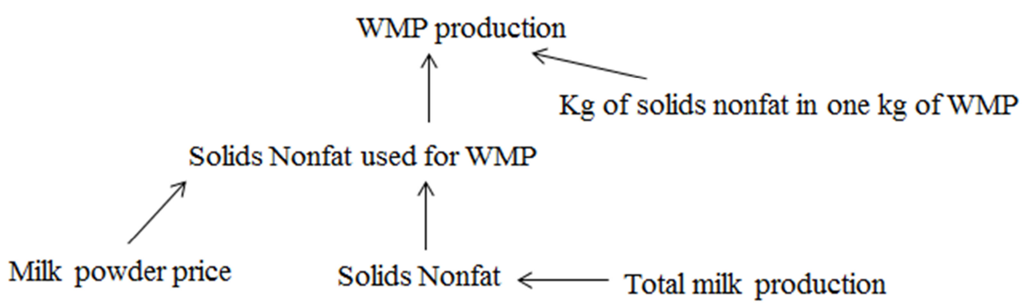

Figure 14. Flow Diagram of WMP Production

Table 25. Solids nonfat used for whole milk powder production

Dependent Variable	Independent Variables	Coefficient	T-statistics
Solids nonfat used	Intercept	14.25	0.57
for WMP	Solids-nonfat used for WMP (t-1)	0.76	6.90
	Milk powder price index/CPIDEF	0.13	0.61
	Total solids-nonfat	0.03	1.73
	D80T00	-42.75	-3.18
	D09	-76.23	-4.43

Note: Breusch-Godfrey LM Test P-Value: 0.33 Adj $R^2 = 0.9829$

The demand side of milk powder consists of exports, domestic consumption and ending stocks. The main component of the demand is the domestic consumption, which represents around 98% of total demand. Domestic consumption was estimated in two equations, representing SMP and WMP consumption, respectively. The simplified diagram is described in Figure 15.

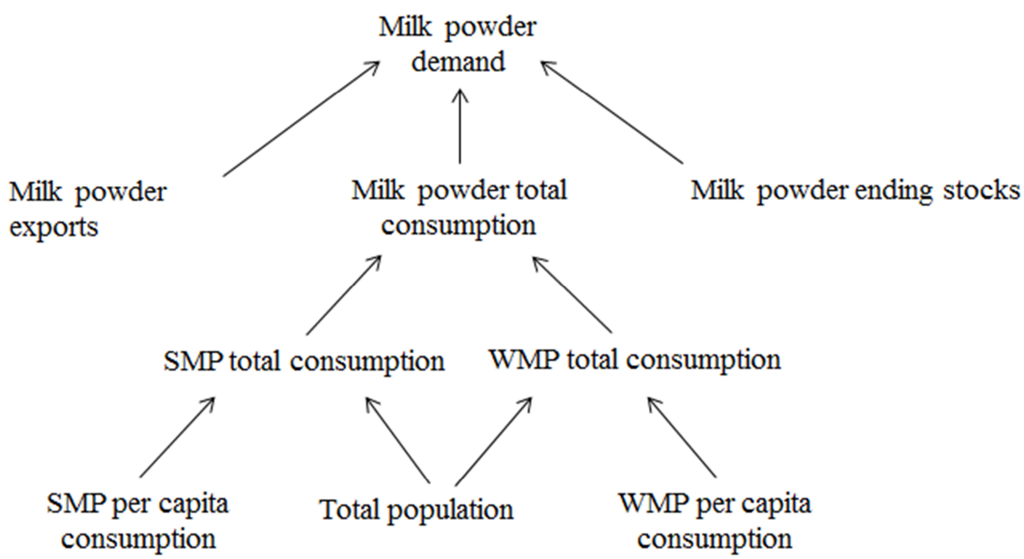

Figure 15. Milk Powder Flow Diagram

Similar to the other dairy products, the volume of milk powder exported from Brazil is not relevant when compared to the domestic consumption. The late-2000s was the only period with relatively more trade. That period combined favorable facts to the Brazilian exports, such as high international prices, a competitive exchange rate, and limited volume in important players like Argentina, Australia and New Zealand. A severe drought in New Zealand as well as in Australia and in Argentina shrunk the global milk output in 2007-2008 raising international dairy prices ((Piesse and Thirtle, 2009), (Von Braun, 2008)). The exported price of whole milk powder in Oceania sharply increased, going from US$ 2,000 per ton in mid-2006 to US$ 5,000 per ton in 2007 according to the international dairy market report (USDA, 2014).

The milk powder export equation was estimated depending on exports lagged one year, deflated milk powder price, exchange rate of *Reais*/US dollar and other exogenous variables as described in Table 26. All independent variable coefficients report the correct sign. However, price and exchange rate were not statistically significant. The exports of milk powder basically follow the exports lagged one year. The serial correlation was checked for consistency and the Breusch-Godfrey test did not detect this problem with a P-value of 0.63.

Table 26. Milk Powder Exports

Dependent Variable	Independent Variables	Coefficient	T-statistics
Milk powder exports	Intercept	-4.17	-0.41
	Milk powder exports (t-1)	0.25	2.35
	Milk powder price index/CPIDEF	-0.01	-0.11
	Exchange rate	3.78	1.83
	D07T08	51.26	8.48
	SHIFT05	3.47	0.82

Note: Breusch-Godfrey LM Test P-Value: 0.63 Adj $R^2 = 0.8170$

In terms of domestic consumption, SMP is not as relevant as WMP. The per capita consumption of SMP is about four times smaller than WMP. Nevertheless, the consumption of both SMP and WMP has been growing over time. The per capita consumption of SMP depends on the milk powder price and the per capita GDP as reported in Table 27. The price is negatively related to the per capita consumption, as expected. The coefficient is not statistically significant, though. It is worth mentioning that the milk powder price represents both SMP and WMP since the disaggregated price is not available. Therefore, the own-price elasticity should be used with caution. Per capita GDP, on the other hand, is strongly significant. Although SMP is inelastic with respect to income, the value is relatively high in comparison with other dairy products. For that reason, it seems that the income effect is much more relevant to the milk powder industry than the price effect. Other exogenous variables were also incorporated in the equation to correct for outliers.

Table 27. SMP per Capita Consumption

Dependent Variable	Independent Variables	Coefficient	T-statistics
Log (SMP per	Intercept	-9.29	-3.93
capita consumption)	log(M. powder price index/CPIDEF)	-0.03	-0.13
	log(GDP per capita)	0.91	3.93
	D86	0.93	5.77
	D96	0.31	2.12
	D82859200	-0.43	-5.32

Note: Durbin-Watson statistic: 1.55 Adj R^2 = 0.7647

As for the per capita consumption of WMP, the own-price elasticity was estimated as inelastic and the coefficient was not statistically significant (Table 28). The per capita consumption was also inelastic to income and not significant. An intercept shifter, on the other hand, is highly significant and was included in the equation to account for structural change in the series since the mid-1990s. Other exogenous variables were added to capture specific trend and outliers.

Table 28. WMP per Capita Consumption

Dependent Variable	Independent Variables	Coefficient	T-statistics
Log (WMP per capita consumption)	Intercept	-3.34	-0.69
	log(M. powder price index/CPIDEF)	-0.04	-0.25
	log(GDP per capita)	0.37	0.76
	log(trend06)	0.12	1.57
	D09T10	-0.06	-0.62
	SHIFT94	0.73	11.07

Note: Durbin-Watson statistic: 1.77 Adj $R^2 = 0.9392$

3.4.4. Fresh Dairy Products Market

Due to data constraints, fresh dairy products were analyzed as a group instead of individually dairy products. The group includes, as the name suggest, fresh dairy in general, such as yogurt, fermented milk, fluid milk, and some kind of cheese, like *Minas Frescal*. The main component of this group is the fluid milk. In terms of price, data constraint also led to using the fluid milk price as a proxy to the entire group. As for conversion, fat and solids-nonfat content were considered as fluid milk as well.

The supply side of the fresh dairy products is described in Figure 16. The main component of fresh dairy supply is production. The volume of imports is marginal and the amount of stocks is nearly zero.

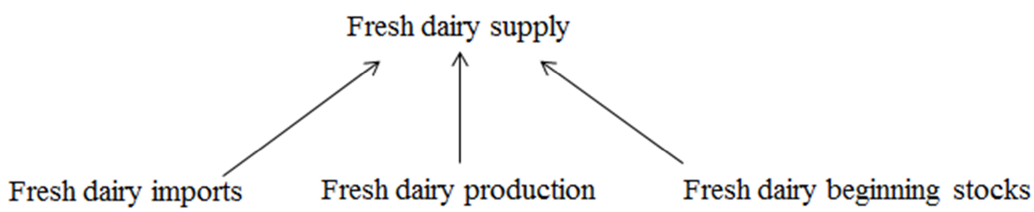

Figure 16. Flow Diagram of Fresh Dairy Products

The total imports of fresh dairy products stayed close to zero until the early-1990s. Then, it expanded until the late1990s and moved back to a low level after that. The import equation is estimated as a function of lagged one year imports, deflated fluid milk retail price, and exchange rate (Table 29). Nevertheless, the retail price is not statistically significant. On the other hand, both the import lagged one year and the exchange rate are significant, and explain most of the variation on fresh dairy imports. The import volume can be described as occasional imports since it is easy to buy from neighboring countries such as Argentina and Uruguay. The null hypothesis of no serial correlation was not rejected at the 10% confidence level according to the Breusch-Godfrey LM Test.

Table 29. Fresh Dairy Products Imports

Dependent Variable	Independent Variables	Coefficient	T-statistics
Fresh dairy imports	Intercept	46.15	2.47
	Fresh dairy imports (t-1)	0.70	8.68
	Fluid milk price index/CPIDEF	0.08	0.43
	Exchange rate	-26.89	-6.14
	D80T94	-13.28	-2.19
	D95T04	30.54	3.66

Note: Breusch-Godfrey LM Test P-Value: 0.13 Adj R^2 = 0.9160

The most important component of the fresh dairy supply is the production. The simplified flow diagram of fresh dairy production is reported by Figure 17. The amount of milk fat used to produce fresh dairy products was estimated depending on lagged one year milk fat used for fresh dairy, deflated fluid milk retail price, and total milk fat available. The retail price coefficient was not significant, while the other variables were strongly relevant to explain variations on fresh dairy production (Table 30). Dummy variables were included to account for outliers. Serial correlation was also checked, and it was not present in the fitted equation according to the Breusch-Godfrey LM Test.

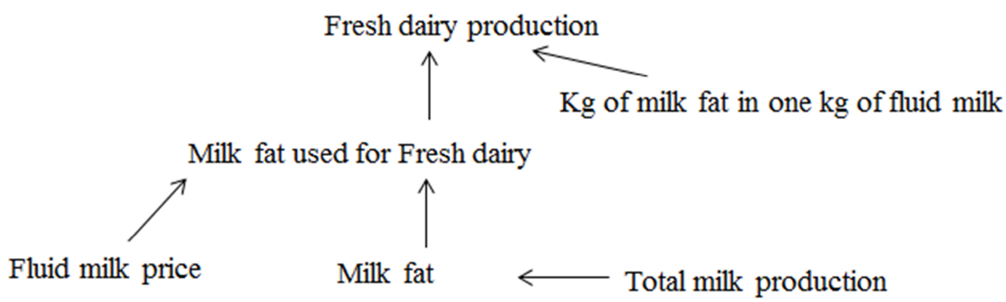

Figure 17. Flow diagram of fresh dairy products

Table 30. Milkfat used for Fresh Dairy Production

Dependent Variable	Independent Variables	Coefficient	T-statistics
Milkfat used for	Intercept	8.60	0.26
fresh dairy	Milkfat used for fresh dairy (t-1)	0.63	4.48
	Fluid retail price index/CPIDEF	0.13	0.52
	Total milkfat	0.13	2.23
	D94	-23.50	-1.30
	D06T08	-28.65	-1.82
	D09T12	13.10	0.81

Note: Breusch-Godfrey LM Test P-Value: 0.14 Adj R^2 = 0.9331

In terms of demand, the simplified diagram for fresh dairy products is described in Figure 18. Once again, the international trade component is not relevant for the fresh dairy market. The volume exported was very close to zero, on average. In fact, the export was zero in many years of the 1980s and 1990s. Nevertheless, the export equation was fitted in terms of retail milk price, exchange rate, and dummy variables (Table 31).

The equation is slightly different than the other export equations because it did not incorporate the lagged dependent variable as a covariate. Since observed zeros were frequent on the series, the inclusion of the lagged dependent variable did not improve the model for goodness of fit. On the other hand, the exchange rate explained most of the variations on fresh dairy exports. The volume exported was more relevant in some specific periods such as in 2007 due to high international dairy prices.

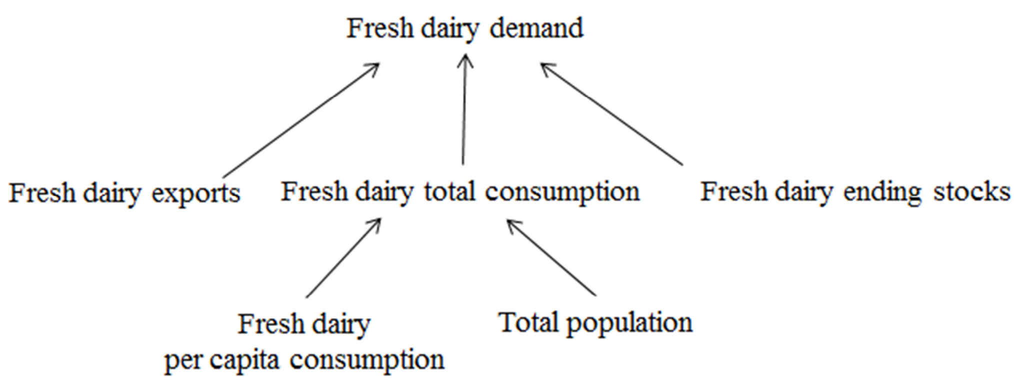

Figure 18. Flow Diagram of Fresh Dairy Products Demand

Table 31. Fresh dairy products exports

Dependent Variable	Independent Variables	Coefficient	T-statistics
Fresh dairy exports	Intercept	-0.03	-0.20
	Fluid retail price index/CPIDEF	-0.0003	-0.26
	Exchange rate	0.06	2.30
	D91	0.19	2.00
	D07	2.04	22.17

Note: Durbin-Watson statistic: 1.87 Adj R^2 = 0.9394

Finally, the per capita consumption was also estimated slightly different than the other dairy products, as can be observed in Table 32. Instead of having only price and per capita GDP on the right hand side of the equation, the lagged dependent variable was included as well. Since the fresh dairy represents a group of products, the behavior of the per capita consumption in the previous year significantly increased the explanatory power of the equation. In fact, the lagged one year dependent variable was the only significant variable in the fresh dairy consumption equation. The own-price and income elasticities were both inelastic. Moreover, these elasticities should be evaluated with care because, again, the fresh dairy represents a group instead of an individual product. Dummy variables were included as well to account for structural changes over time in the series. Those changes are described by stabilization of the consumption during the 1980s, and decline in the mid-2000s and a fast expansion after 2009. The Breusch-Godfrey LM Test was run and failed to reject the null hypothesis of no serial correlation.

Table 32. Fresh Dairy Products per Capita Consumption

Dependent Variable	Independent Variables	Coefficient	T-statistics
Log (fresh per	Intercept	-0.66	-0.41
capita consumption)	log(fresh per cap. consumption)(t-1)	0.84	5.25
	log(fluid price index/CPIDEF)	-0.02	-0.18
	log(GDP per capita)	0.14	1.15
	D80T90	0.02	0.56
	D04T06	-0.04	-1.04
	D09	0.13	1.82

Note: Breusch-Godfrey LM Test P-Value: 0.70 Adj $R^2 = 0.6503$

3.4.5. Residuals Market

The last part of this chapter is used to describe the procedure adopted to account for the informal market in the model. This market represents the share of the milk production that has been consumed without passing through formal manufacturers, and includes subsistence consumption at the farm level and milk or milk products sold directly by farmers (or small companies) that do not have a formal inspection (or it is not reported in the milk statistics). The most common products that compose the informal market are cheese (like fresh cheese) and fluid milk, which do not require much investment on the production process.

Figure 19 reports a simplified flow diagram of milk production. As for the residuals fat, first of all, the percentage of the total milk fat that is represented by the residual market was estimated. In 1980, around 33% of the total fat production flowed into the informal market. This share decreased to 29% in 1990 and then to around 26.5% in 2012. Therefore, the informal market has declined over time because a greater share of the total production has been incorporated into the formal market. As for the estimation, the residual share equation was estimated on the time trend variable, and the results are summarized in Table 33. Outliers were accounted for by including dummy variables. The Durbin-Watson statistics, originally equal 0.754, suggested first order serial correlation. As pointed in Wooldridge (2009) under certain conditions the OLS estimators are still unbiased, regardless of the degree of serial correlation in the errors. However, the first order serial correlation problem was fixed using the Prais-Winsten estimator described in Prais and Winsten (1954) and Greene (2008). The new Durbin-Watson statistic increased to 1.75 and no longer indicates serial correlation.

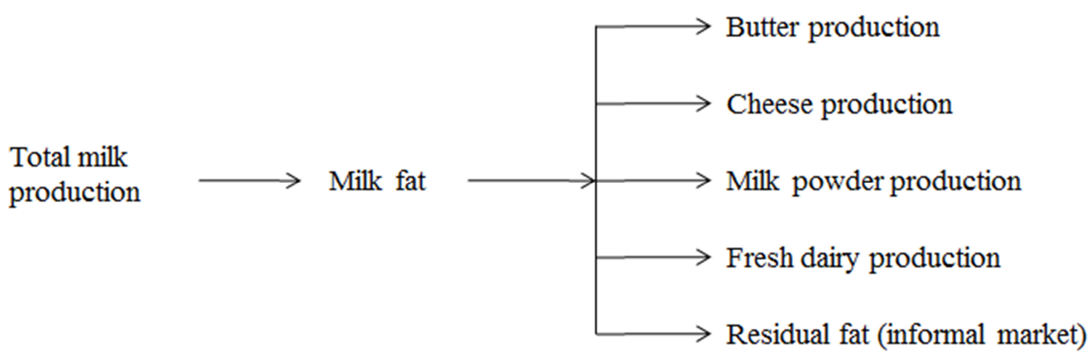

Figure 19. Flow Diagram of Milk and Milk Products Production

Table 33. The Residual of Milk Fat as a Share of Total Milk Fat

Dependent Variable	Independent Variables	Coefficient	T-statistics
Residual of milk fat (%	Intercept	0.33	31.19
of the total milk fat)	Trend	-0.002	-3.78
	D93T95	0.03	5.21
	D96T97	-0.04	-5.72
	D07	0.02	3.12

Note: Durbin-Watson statistic: 1.75 Adj $R^2 = 0.9362$

CHAPTER IV

DETERMINISTIC POLICY ANALYSIS

In terms of forecast and for policy consideration, this study employs three different approaches to investigate how the dairy sector in Brazil reacts to exogenous shocks. Those approaches include the baseline scenario, the deterministic shocks evaluation, and the stochastic shocks. The last two approaches are discussed in chapters V and VI, respectively. The baseline scenario considers the *status quo* of the exogenous variables, described in in Table A-1 in Appendix. The same variables are used for the deterministic analysis, presented in the next chapter. The main exogenous variables are defined as following:

1) The GDP growth rate: the actual growth rates are used until 2013. After that, the forecast is based on the scenario published by Santander Bank, located in Brazil;

2) Nominal interest rate: the same level of 2012 is used to represent 2013-2022 and has the Central Bank as the source;

3) Sugar cane acreage: the 2012 level is set to the whole period and the data came from IBGE;

4) Minimum price of milk: the 2013-2015 values were already defined and are incorporated for that period. After that, the 2015 price is set as the reference; and

5) Corn and soybean prices in the US: the forecast data is provided by the Agriculture and Food Policy Center (AFPC), located at Texas A&M University, according to their renewable fuel standard scenarios (Rhew, 2014).

The exogenous variables, presented in Table A-1, affect the behavior and level of the endogenous variables for the 10-year forecasts. Since the whole model is composed of a large number of endogenous variables, the analysis is focused on some key variables that represent the dairy supply, demand, and prices. The total milk production in Brazil is presented in Table 34. The baseline forecast is in between the scenarios developed by both OECD/FAO (2013) and the Brazilian Ministry of Agriculture (MAPA, 2013). It is worth mentioning that in our baseline scenario the world's economy is assumed to perform somewhat worse in the next ten years compared to the last decade. For that reason, the overall growth rate is lower than that of the previous period, as described in Table 35. The production per cow is expected to grow a little faster than before, but it is still very low, with annual production smaller than 2,000 kg/cow by 2022. An expected lower number of dairy farms and greater competition with alternative agricultural activities may cause management improvement for the coming years, inducing better use of technologies. The details of the estimated results are summarized in Tables A-2 and A-3 in the Appendix.

Table 34. Total Milk Production in Brazil: in 1,000 Metric Tons

2012	2022		
	Baseline	OECD-FAO (1)	MAPA (2)
33,055	41,649	38,839	44,514

Note: (1) OECD-FAO outlook 2013-2022; (2) MAPA: Brazilian Ministry of Agriculture.

Table 35. Baseline Scenario for Dairy in Brazil

Variable	2002 (a)	2012 (b)	2022 (c)	2012/2002 ((b)/(a)-1)*100	2022/2012 ((c)/(b)-1)*100
Dairy cow (1,000 heads)	18,792.70	23,482.70	26,737.49	24.96%	13.86%
Yield per cow (kg/cow)	1,286.58	1,407.63	1,557.70	9.41%	10.66%
Milk production (1,000 ton)	24,178.40	33,055.00	41,649.00	36.71%	26.00%
Butter production (1,000 ton)	70.00	81.00	96.94	15.71%	19.68%
Cheese production (1,000 ton)	470.00	700.00	918.64	48.94%	31.23%
Milk powder production (1,000 ton)	462.00	691.00	907.39	49.57%	31.32%
Fresh dairy production (1,000 ton)	10,976.60	14,991.50	18,240.67	36.58%	21.67%
Butter consumption (1,000 ton)	77.20	85.80	98.93	11.14%	15.30%
Cheese consumption (1,000 ton)	478.60	726.40	931.35	51.78%	28.21%
Milk powder consumption (1,000 ton)	571.60	779.20	973.50	36.32%	24.94%
Fresh dairy consumption (1,000 ton)	11,004.10	15,008.20	18,252.61	36.39%	21.62%

As for the rest of this chapter, the baseline scenario is described for different groups of variables that compose the supply, demand, and prices. The first group to be analyzed is made up of number of dairy cows, milk production and production per cow. These variables provide insights into milk availability for the next ten years (Figure 20). As can be observed, both the total milk production and the production per cow will grow consistently. The number of dairy cows, on the other hand, is expected to increase a little slower. This result suggests that the contribution of the dairy cow expansion to the milk production tends to decrease in the long-run. Therefore, the adoption of appropriate technology that impacts the production per cow has to be accounted for by policymakers. As for the milk price, the baseline scenario suggests a slow increase over the decade.

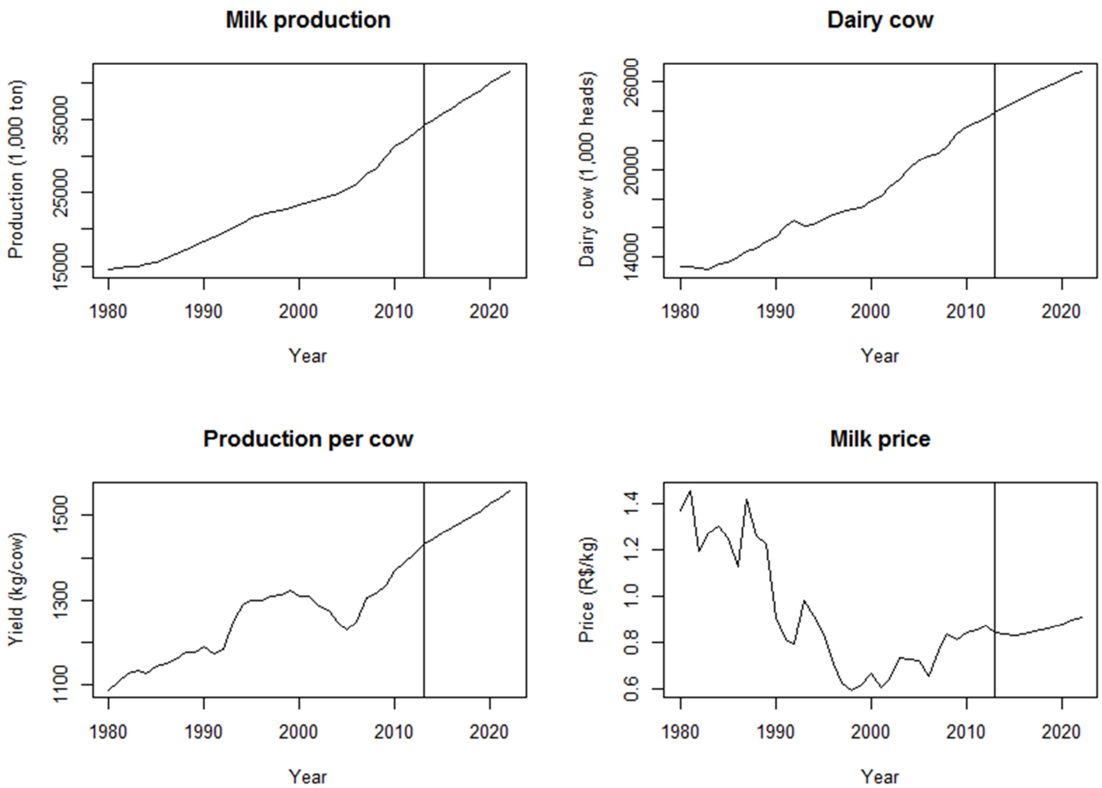

Figure 20. Brazil: Milk Production, Dairy Cow, Production per Cow, and Milk Price
Note: The vertical line defined the first forecast, at 2013.

In case of the butter market, both the production and the consumption are expected to grow consistently during the forecast period (Figure 21). On the other hand, the net import and retail price seems to stay steady around recent levels. Moreover, Brazil will still hold the position of a net importer in the butter market, but with a smaller volume purchased. In fact, becoming a net exporter is an old ambitious for Brazil. In 2012, the Brazilian Export and Investment Promotion Agency (APEX-BRAZIL) approved an international project for the dairy industry that includes investment in promotional materials for milk and milk products abroad. However, our findings indicate that the country is going to hold the net import position in all dairy products. Updates of this model should, eventually, consider future structural changes in dairy trade.

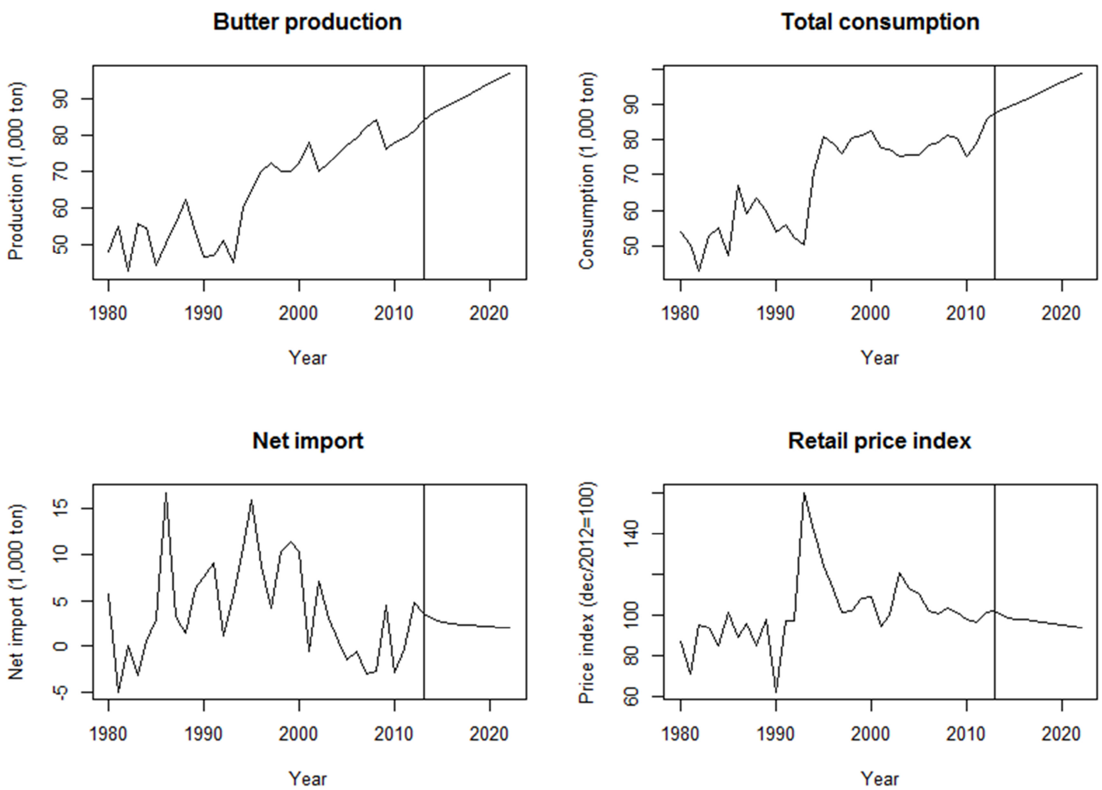

Figure 21. Butter Market: Production, Consumption, Trade, and Retail Price Index
Note: The vertical line defined the first forecast, at 2013.

The cheese market is one of the most important in the Brazilian dairy industry. Both cheese production and consumption have regularly increased as can be observed in Figure 22. One important characteristic of this market is that cheese consumption is relatively more sensitive with respect to income than the other dairy products. The behavior of consumption as well as production is closely related to the Brazilian economy and domestic income. Coelho, et al. (2010) found income-elasticity for cheese in Brazil of 1.13, which supports the idea that cheese consumption is closely related to per capita income.

As for trade, the country is a net importer of cheese and the volume purchased will stay, on average, similar to the historical level. Due to high per capita income, a faster growth rate of cheese imports is expected after 2016. The consumer price of cheese may reflect similar increase after 2016 as well.

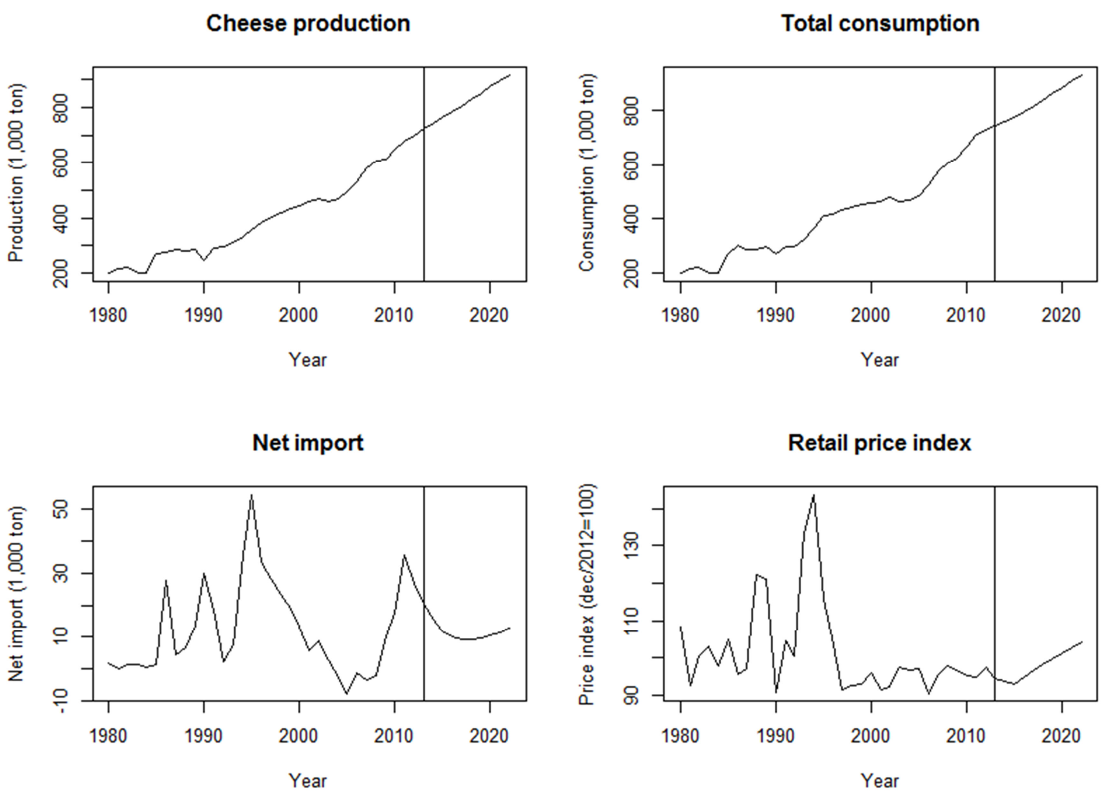

Figure 22. Cheese Market: Production, Consumption, Trade, and Retail Price Index
Note: The vertical line defined the first forecast, at 2013.

The milk powder market is growing as fast as the cheese market. Both the production and the consumption will improve during the coming years as reported in Figure 23. Moreover, milk powder is more relevant than the other dairy products in terms of international trade. The net import forecasts suggest steady volume at recent levels, which means that Brazil will hold the net importer position in the milk powder market. Nevertheless, the ratio between net import and production is expected to decline over time, reflecting greater expansion in the production relative to net imports. The consumer price of milk powder, on average, will stay at the historical mean level. It is also expected to grow somewhat faster after 2016 due to higher per capita income.

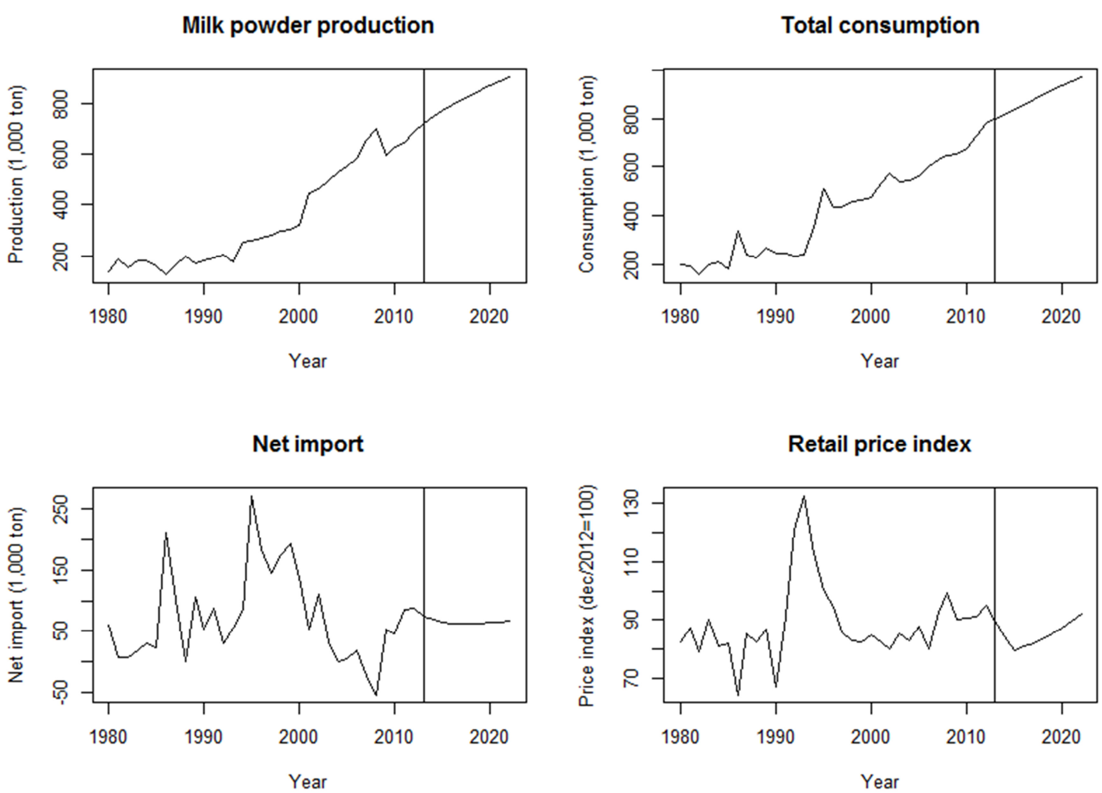

Figure 23. Milk Powder Market: Production, Consumption, Trade, and Retail Price Index

Note: The vertical line defined the first forecast, at 2013.

As for the group of fresh dairy products, both the production and the consumption were flat during the 1990s and early-2000s (Figure 24). However, in the late-2000s, the fresh dairy market rapidly increased. Expansion of per capita income boosts the consumption of yogurt, fresh cheese and other dairy products. Given the perishable characteristics of the products in this group, international trade is not an important component of this market. Except for some imports in the middle and late-1990s, overall the volume of fresh dairy purchased is small and tends to stay at the low level during the coming years. The consumer price is expected to stay around the historical mean, growing a little faster after 2016 as a consequence of expected better income.

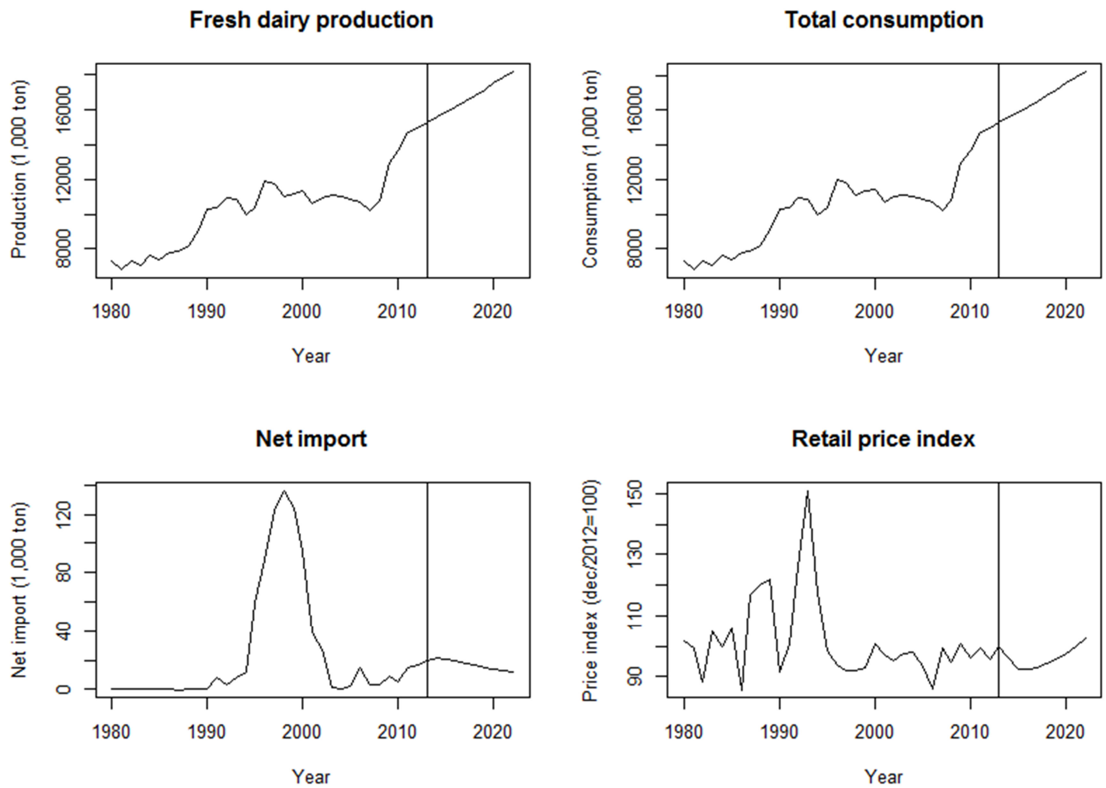

Figure 24. Fresh Dairy Products Market: Production, Consumption, Trade, and Retail Price Index
Note: The vertical line defined the first forecast, at 2013.

The last part of this chapter consist of an exercise to evaluates how balanced is this dairy model. Basically, the model is well balanced if the total milk fat left over, after being used to produce milk products in both formal and informal markets, is small. The results give us some idea of how the model handles the forecast of milk fat supply and use. The amount of milk fat left over was lower than 2.0% of the total milk fat available (Figure 25). Therefore, the model seems to be well balanced. By taking into account the scarcity of data in Brazil, and the effort to combine different sources of data to make this model feasible, the result looks meaningful.

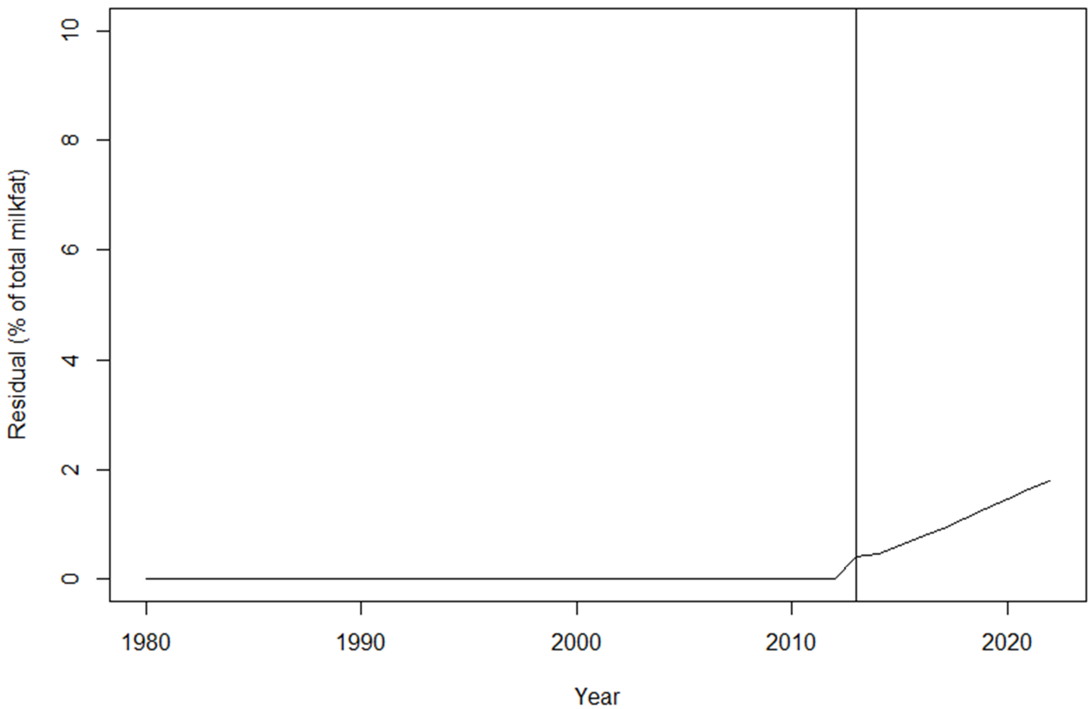

Figure 25. Milk Fat Left Over as a Percentage of the Total Milk Fat Available (%)

CHAPTER V

ELASTICITIES AND SENSITIVITY ANALYSIS

The objective of the chapter is to evaluate how the dairy industry in Brazil reacts to shocks, such as changes in feed cost, GDP, interest rate, minimum price, and sugar cane acreage. The conceptual analysis is presented in the first part of the chapter to clarify the impacts of shocks on the supply chain, considering the price/quantity space. The second section is devoted to developing the empirical framework that allows us to measure the effects of policy changes.

5.1. Conceptual Analysis

The supply and demand analysis in competitive markets is the basic analytical tool throughout this section. Although the data related to wholesale prices and quantities is not available, for completeness, most of the scenarios take into consideration the effects of shocks on the farm, wholesale, and retail levels. By using the graphical framework, the impact of shocks on the dairy industry can be easily observed in the price/quantity space. Details and basic definitions about the analytical framework are described in Gardner (1987).

5.1.1. Demand Shock

Figure 26 illustrates the impact of positive changes in per capita GDP on the supply chain, considering the price/quantity space. The impact on price/quantity can be analyzed considering different supply responses. In the first case, the milk supply responds to the price stimulus, while in the second case the supply curve is perfectly inelastic to price changes.

Under the first case, the farm level price (P_F) and quantity (Q_F) represent the initial equilibrium. The wholesale and the retail prices are defined as P_W and P_R, respectively. After the GDP shock, the demand curve (D) shifted to the right to a new demand curve, illustrated by D'. The new equilibrium price/quantity is now represented by P'_F and Q'_F. The wholesale price increased to P'_W and the consumer price moved up to P'_R.

However, under the assumption of a perfectly inelastic supply curve, the new equilibrium prices would be somewhat higher, represented by P''_F, P''_W, and P''_R. Hence, the consumer would pay a higher price for dairy products in Brazil if the per capita GDP increases faster than in the base scenario.

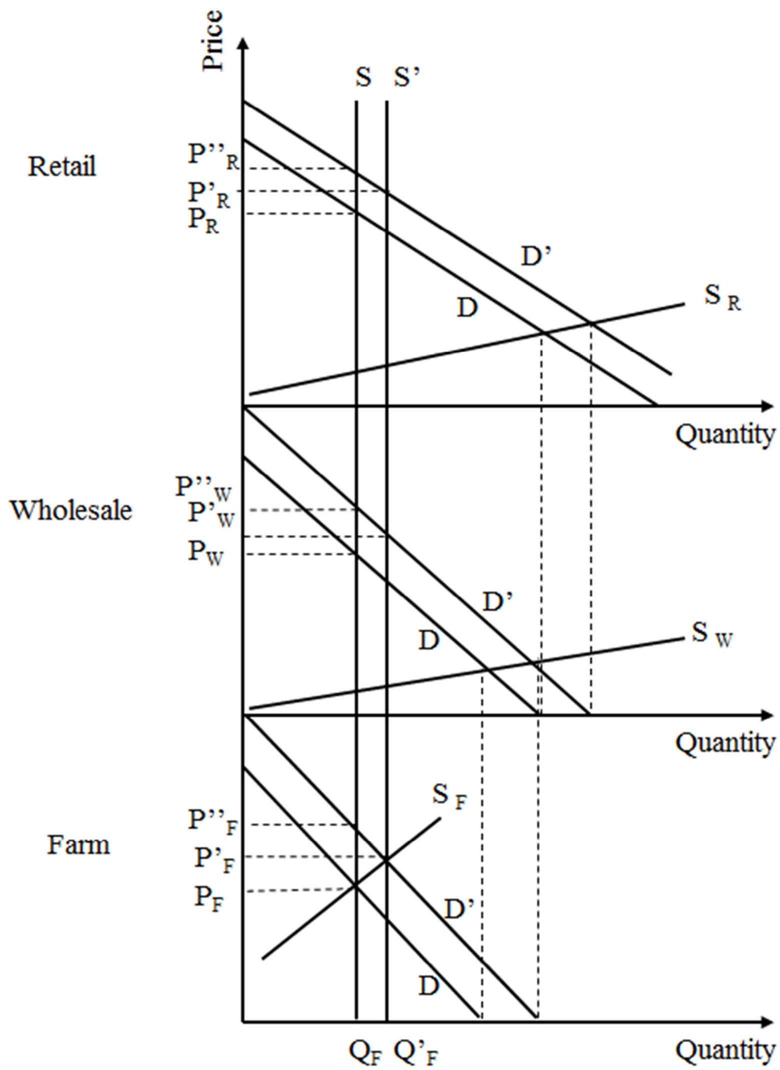

Figure 26. Positive Demand Shock on the Dairy Supply Chain

5.1.2. Supply Shock

Figure 27 represents a negative shock in the milk supply at the farm level, which shifts the supply curve to the left. Some examples of negative shocks in the context of the study are an increase in feed cost, an expansion of sugar cane acreage, and a rise in interest rates for dairy farms. Suppose, for example, the removal of the subsidized interest rate for rural credit, which would increase the actual interest rate and the cost of milk production. Such a policy would shift the supply curve to the left reaching the new price/quantity equilibrium at P'_F and Q'_F as represented in Figure 27. The total milk production is now represented by S' and the wholesale and retail prices by P'_W and P'_R, respectively. Therefore, an increase in the cost of milk production would lead to a lower supply and higher prices in the entire supply chain. On the other hand, a reduction in the cost of milk production would have the opposite impact, with a higher supply and lower prices.

The expansion of sugar cane acreage in São Paulo can be analyzed in the same manner described in Figure 27. However, the shift of the supply curve to the left is caused by the reduction of the number of dairy cows on a farm instead of the increase of the cost of milk production. Therefore, the drop in the milk supply would end up increasing the milk price throughout the supply chain.

Another simplified diagram that helps to illustrate the impact of changes in the cost of production on the dairy supply is described by Figure 28. Let us consider the RFS program in the United States, which has increased the demand for corn to produce ethanol. In the corn market, the introduction of the RFS mandate shifted the corn demand to the right. The new price/quantity equilibrium in the corn market is described by P'_C and Q'_C. On the other hand, a high corn price negatively affects the corn demanded by the dairy industry through the derived demand function. In addition, the lower use of input (corn) shrinks the level of dairy output, defined as the total milk production. This move can be observed on the total physical product (TPP) graph, which is the total production of output by a firm based on the quantity of inputs used. The new price/quantity equilibrium in the dairy market is represented by P'_D and Q'_D, which are actually P'_F and Q'_F in Figure 27.

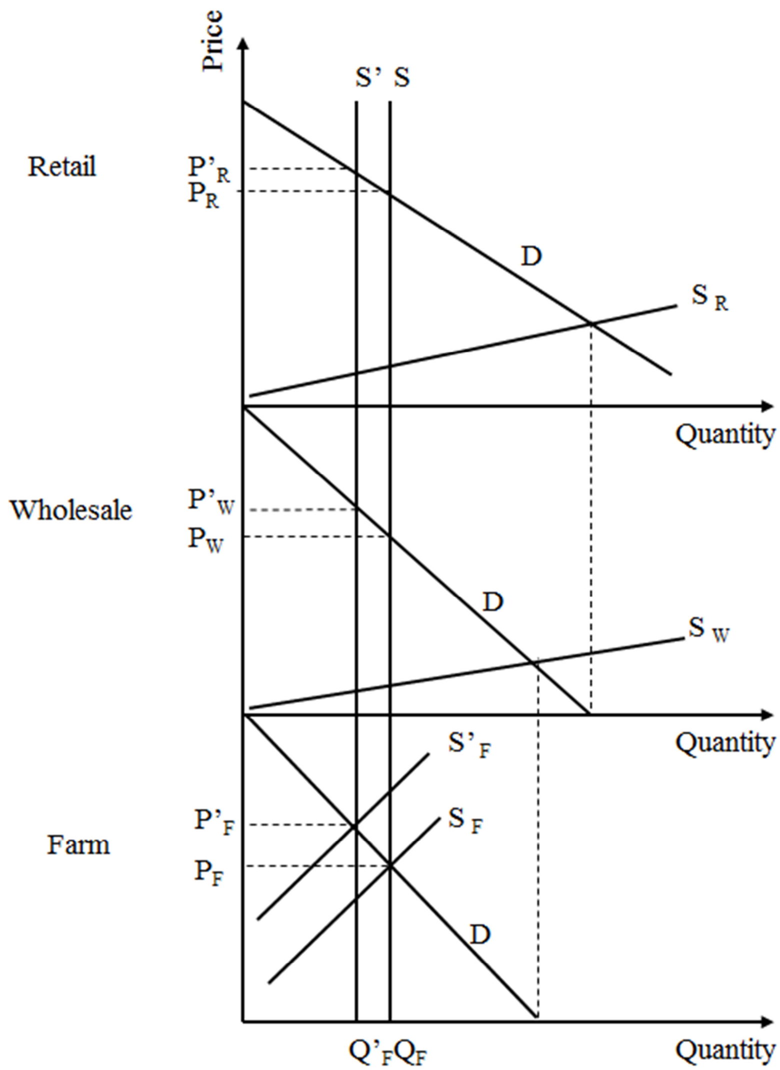

Figure 27. Negative Supply Shock on the Dairy Chain

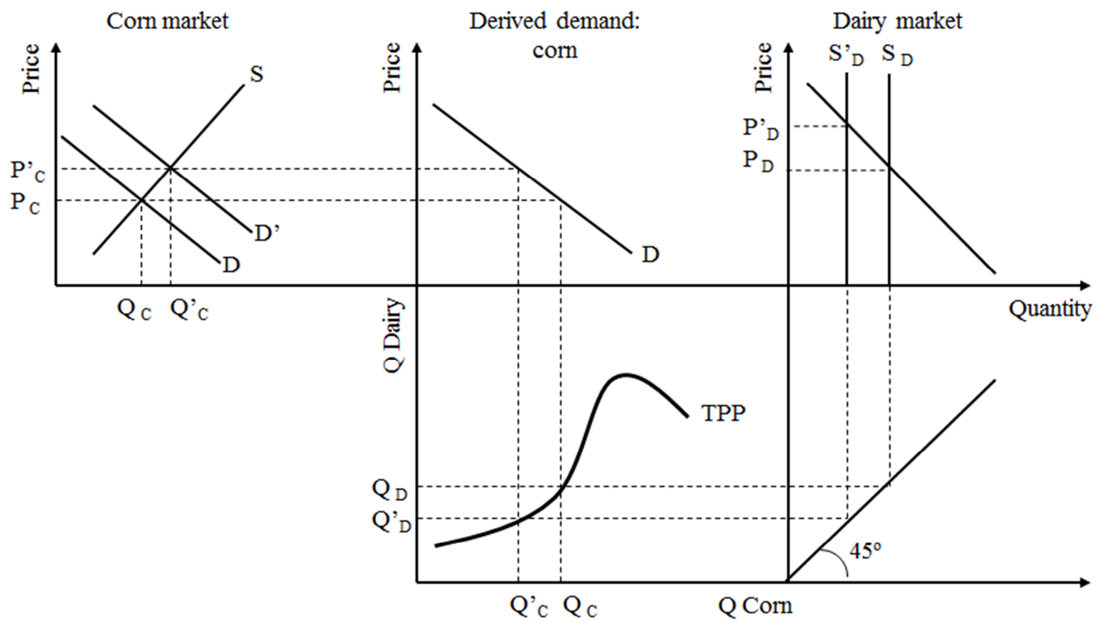

Figure 28. RFS Requirement Program on the Dairy Industry

5.1.3. Government Intervention

Government interventions have played an important role in many countries with a variety of objectives, such as encouraging food supply, supporting farm revenue, protecting domestic industries, and promoting exports. In Brazil, one of the dairy policies in place refers to a price support, also called minimum price guarantee. Figure 29 illustrates this policy. Let us consider the equilibrium price/quantity represented by P_F and Q_F in the bottom graph. The wholesale and retail prices are represented by P_W and P_R, respectively. The government sets the minimum price at P'_F and in case the market price falls below the minimum, the government will guarantee the minimum price described by P'_F. Using such a policy the government limits the risk price because the probability distribution function becomes truncated from below. However, the policy has some costs and the government has to pay the difference between the minimum price and the actual price if it goes below the minimum. In addition, the government may have to deal with the cost of holding stocks or trade the volume into the market.

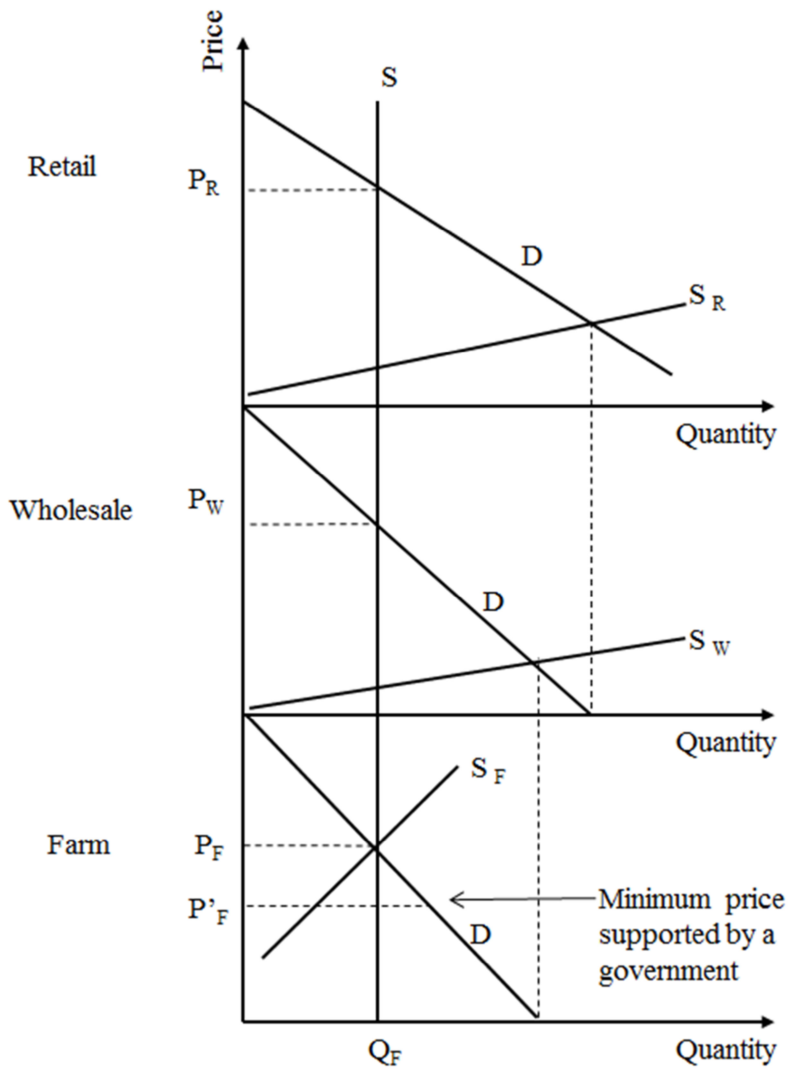

Figure 29. Minimum Price Policy on the Dairy Supply Chain

5.1.4. Production Research

The impact of technological advances that reduce the cost of production or improve the efficiency has a strong effect on the entire supply chain, and ends up reducing the consumer price as well as expanding the dairy supply. Consider the initial price/quantity equilibrium determined by P_F, Q_F, P_W, and P_R as presented in Figure 30. Gains in efficiency at the wholesale level moves the supply curve from S_W to S'_W,. At the farm level, the demand curve will be shifted to the right from D to D' and the quantity from Q_F to Q'_F. The new price/quantity equilibrium is now reached at P'_F, Q'_F, P'_W, and P'_R. Therefore, the improvement in efficiency at the wholesale level leads to a higher farm level price, higher quantity supplied and lower prices at retail and wholesale. Similar results are observed if the gain in efficiency happens at the retail level.

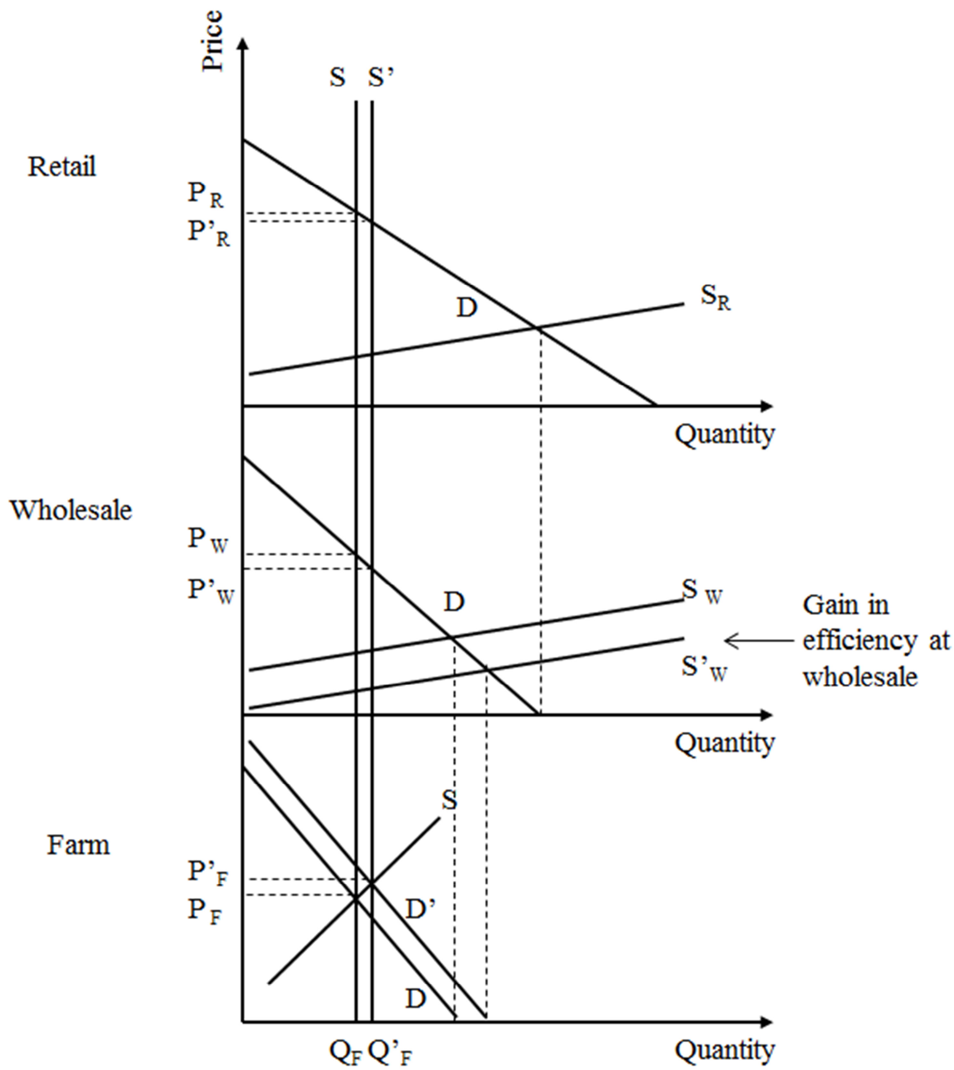

Figure 30. Effects of Efficiency Gain at the Wholesale Level

Finally, suppose the efficiency gain occurs at the farm level as a result of genetic improvement, a better production system, or any technology that reduces the cost of milk production. The initial price/quantity equilibrium is characterized by P_F, Q_F, P_W, and P_R as presented in Figure 31. The use of new technology at the farm level moves the supply curve to the right, from S_F to S'_F. The total milk production increases up to Q'_F and both the wholesale and retail prices drop to P'_W and P'_R, respectively. Hence, technological advances have the benefit of expanding the total dairy supply and reducing the consumer price.

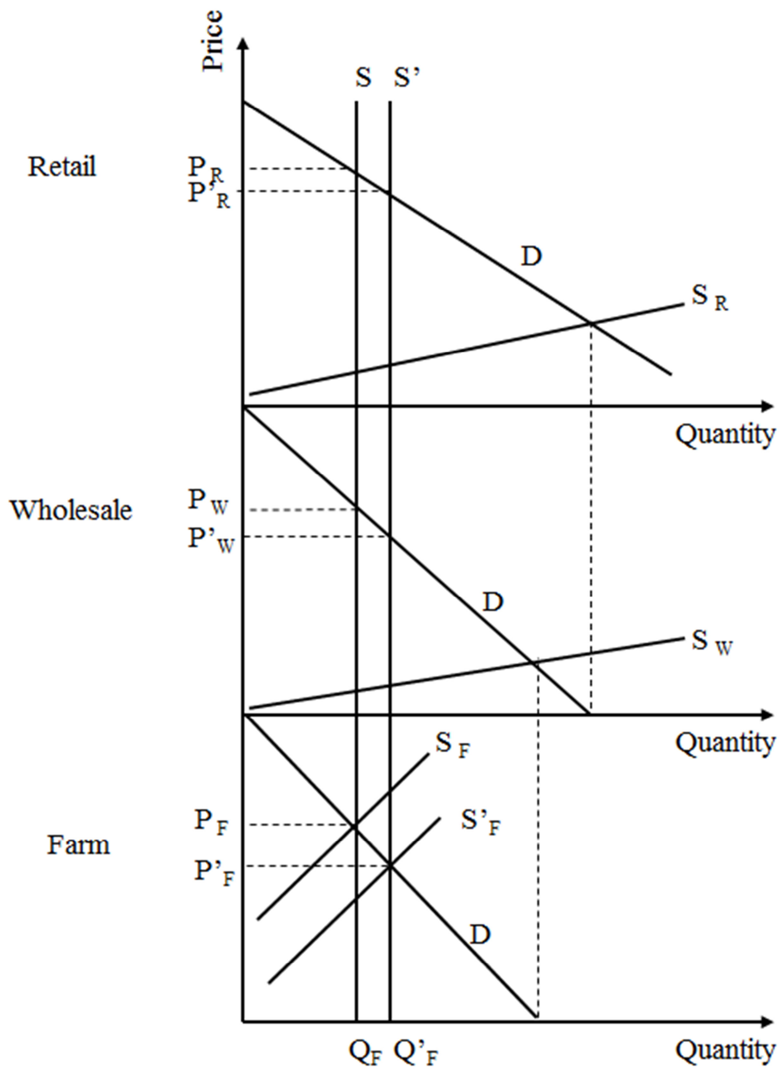

Figure 31. Effects of Efficiency Gain at the Farm Level

5.2. Empirical Analysis

In this section, the empirical analysis of how the dairy sector reacts to shocks is performed. Basically, the alternative scenarios are contrasted with the baseline scenario. The impacts of these shocks on price and quantity are measured. It is worth remembering that the baseline scenario represents the *status quo* for the policies and has the following assumptions:

1) The GDP growth rate at 2.5% per year after 2016 and it is based on the scenario published by Santander Bank;
2) The nominal 2012 interest rate for rural credit is used to represent the 2013-2022 period;
3) The minimum prices of milk for 2013-2015 were already published and are incorporated for that period. After that, the 2015 price is set as the reference;
4) The forecast for corn and soybean prices in the US are based on the Agriculture and Food Policy Center (AFPC) scenarios; and
5) Sugar cane acreage is set at the 2012 level for the entire period.

However, for the alternative scenarios, the status quo of the exogenous variables is replaced by the values presented in Table A-4 in the Appendix. That is:

1) The GDP growth rate is assumed to be higher from 2016 and after (3.5% per year);
2) The subsidized interest rate is replaced by the reference interest rate in the Brazilian economy, called *Selic*, using the 2012 level to represent the 2013-2022 period;
3) The minimum milk price is set at 50% higher than the 2012 value, and the same value is used until 2022;

4) The US corn and soybean prices reflect the AFPC scenario in the absence of RFS requirements; and
5) The sugar cane acreage in *São Paulo* expands linearly 30% from 2012 to 2022.

In terms of model specification, changes in GDP are captured directly through dairy consumption and therefore transmitted to prices and production. The subsidized interest rate and the minimum milk price guarantee are incorporated in the model through the net revenue, which influences both the number of dairy cows and the production per cow. In the case of RFS, the model includes only the direct effect of RFS on the US corn and soybean prices. Then, by modeling the grain prices in Brazil as a function of US grain prices, the RFS effects are transmitted to corn and soybean prices in Brazil. However, the eventual effects of RFS on corn and soybean acreages in Brazil, which may change grain prices as well, are not accounted for. Finally, the sugar cane acreage expansion in *São Paulo* is considered in the equation for the number of dairy cows. The details of the estimated results that compare the baseline and alternative scenarios are summarized in Tables A-5 in the Appendix.

5.2.1. GDP Shock

The first scenario analyzed is the GDP shock. The main difference between this scenario and the baseline scenario is that the former assumes an annual growth in GDP of 3.5% starting in 2016, while the latter assumes 2.5%. A higher expansion of GDP shifts the demand curve to the right and increases the consumer price. At the farm level, Figure 32 illustrates the impacts of a higher GDP on the milk production and milk price.

For a one percentage point increases of GDP, the milk production increases, on average, 0.4% considering the whole period. Moreover, the production in 2022 will be half of a million tons higher than the production under the baseline scenario. The milk price will be, on average, 5.6% higher than the baseline price considering the 2013-2022 period.

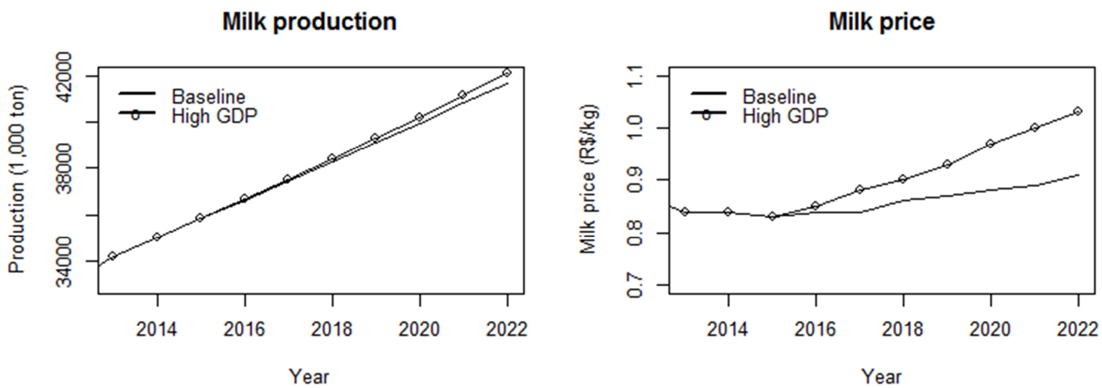

Figure 32. GDP Effects on the Milk Production and Milk Price

As for the consumer point of view, the expansion of the GDP positively impacts the total consumption of dairy products and the retail prices as described in Figures 33 to 36.

The largest impact on consumption occurs on the cheese market (Figure 34) followed by the milk powder market (Figure 35) because the income elasticity of those products is higher than the income elasticity of the other dairy products. Results published by Coelho, et al. (2010) and Hoffmann (2000) concur with the findings of this research since they estimated high income-elasticity for cheese in Brazil.

The fluid milk price will increase, on average, around 11.6% compared to the baseline mean price from 2013-2022. Milk powder prices will be 10% higher, while the cheese price will rise 6.6%. Butter prices, on the other hand, are not very sensitive to changes in GDP. Therefore, changes in income play an important role on the Brazilian dairy industry by causing expansion in consumption. Since the Brazilian per capita income is relatively low, any gain in terms of income would be extremely important for the consumption of dairy products (and food in general).

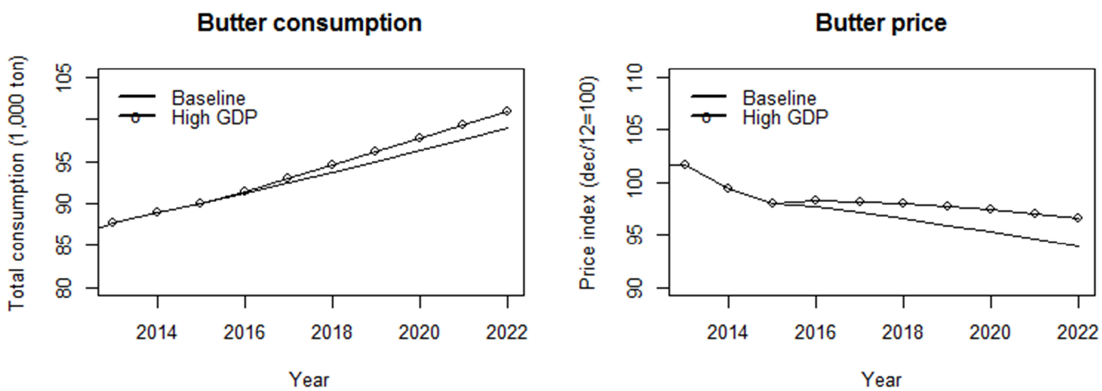

Figure 33. GDP Effects on the Butter Market

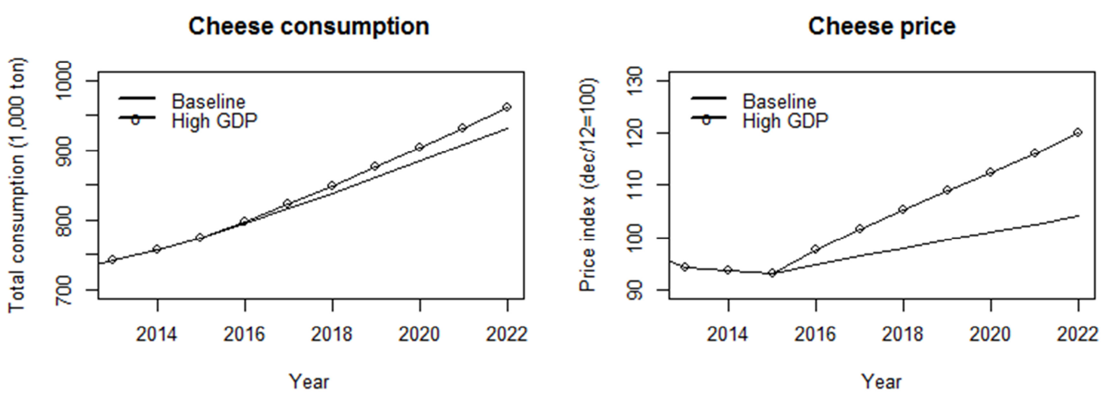

Figure 34. GDP Effects on the Cheese Market

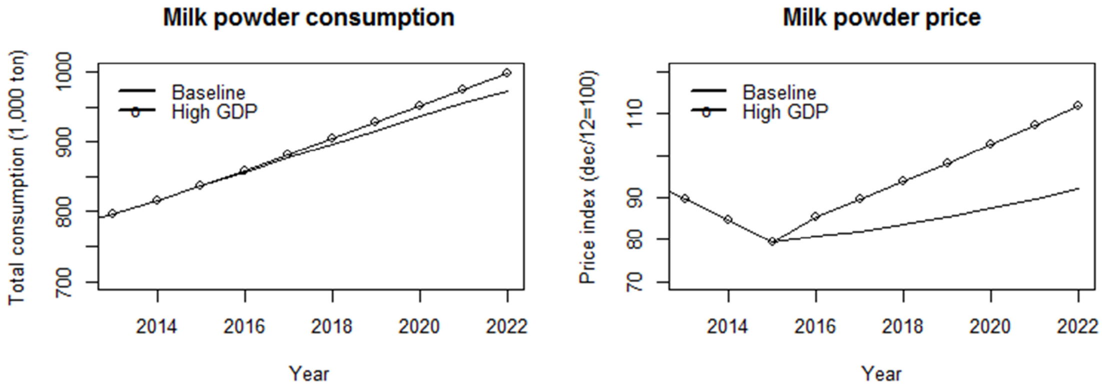

Figure 35. GDP Effects on the Milk Powder Market

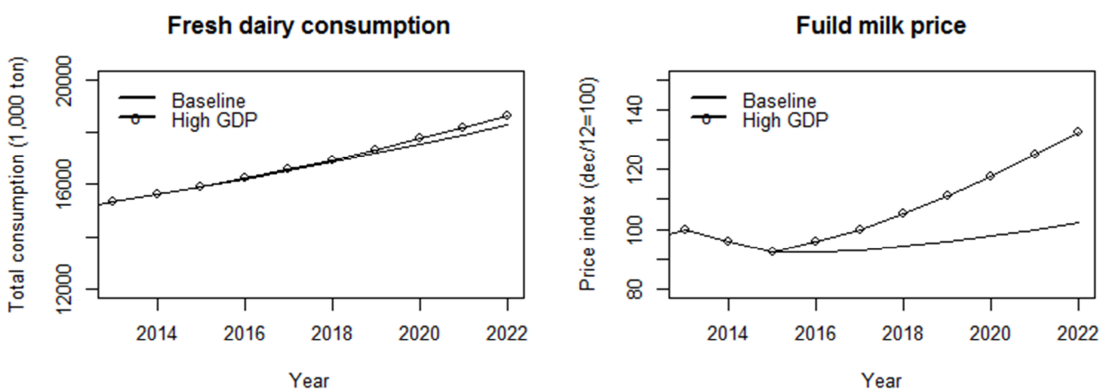

Figure 36. GDP Effects on the Fresh Dairy Market

5.2.2. No Subsidized Interest Rate

One of the most common dairy policies in Brazil is a subsidized interest rate. The policy consists of providing credit to farms with low interest. As for the model's estimation, the cost of credit is accounted for in the net revenue, which is then used to estimate equations for dairy cows and production per cow. Since the baseline scenario assumes the current policy (subsidized interest rate), the alternative scenario considers the absence of such a policy. The reference interest rate for the entire economy, called Selic, is used as the cost of credit for the purposed shock. The impacts of the removal are somewhat underestimated because the actual cost of credit has additional transaction costs not accounted for by the Selic interest rate.

Figure 37 shows the influence of eliminating the subsidized interest rate on the milk production and price. As can be observed in Figure 37, the negative effect of a higher interest rate on milk production is just marginal. The total production decreases slightly. The milk price, on the other hand, would rise about 1.2%, on average, in the absence of subsidized interest rate.

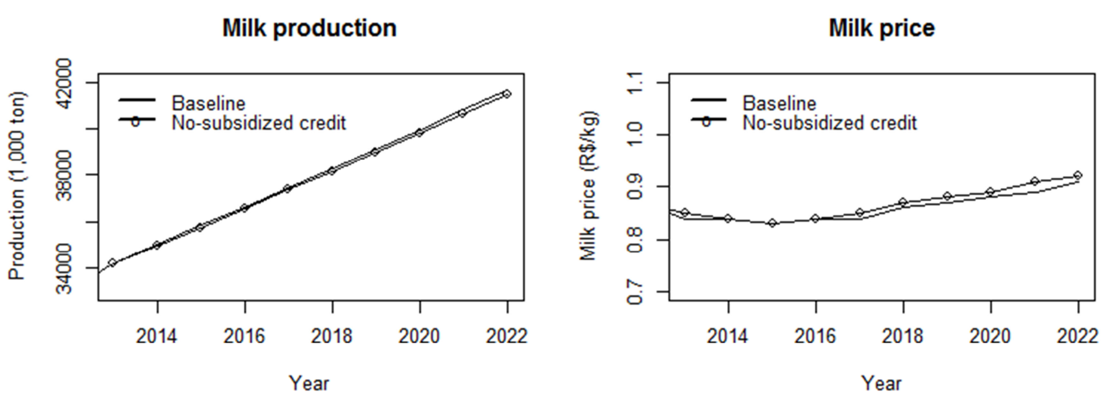

Figure 37. No Subsidized Credit Effects on the Milk Production and Milk Price

The elimination of subsidized interest rate has a very low effect on total consumption of dairy products as reported in Figures 38 to 41. In terms of consumer price, the absence of such a policy causes a small increase. The fluid milk price is the most sensitive, and on average it goes up by 2.5%. Nevertheless, the absence of the policy would not cause significant loss to the Brazilian dairy sector nor to consumers, based on the procedures, assumptions, and findings of this study.

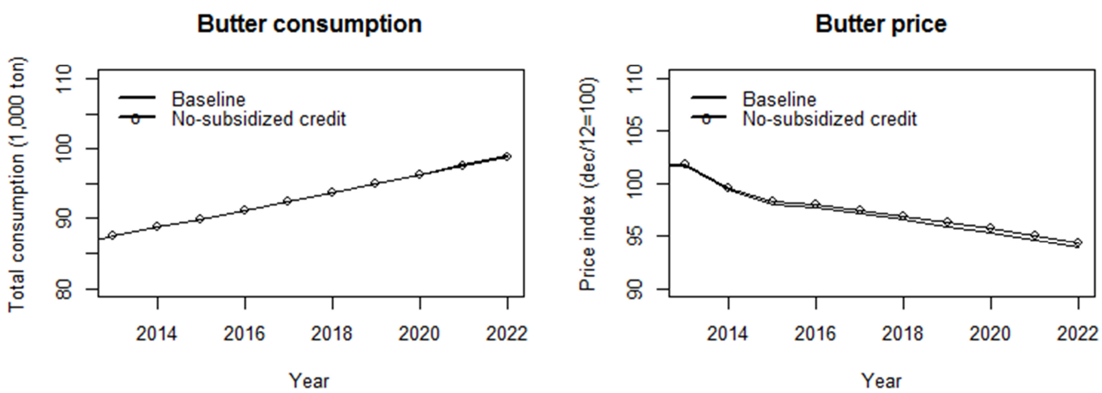

Figure 38. No Subsidized Credit Effects on the Butter Market

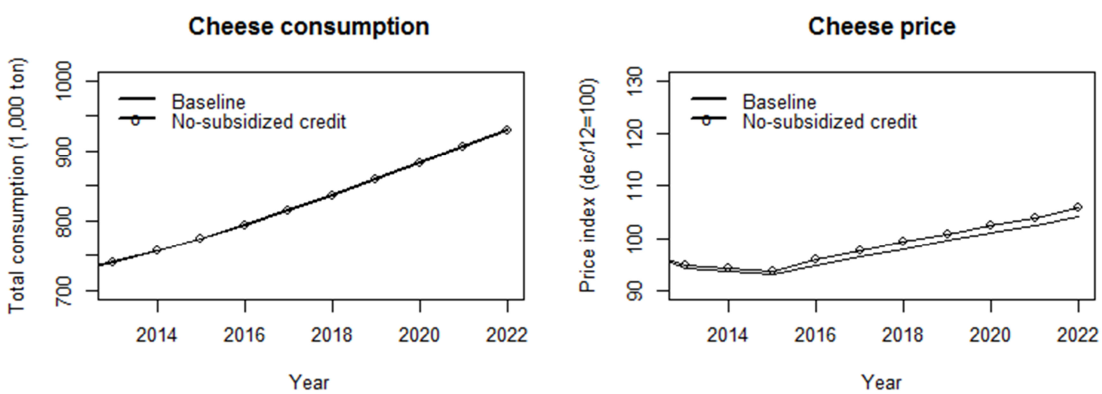

Figure 39. No Subsidized Credit Effects on the Cheese Market

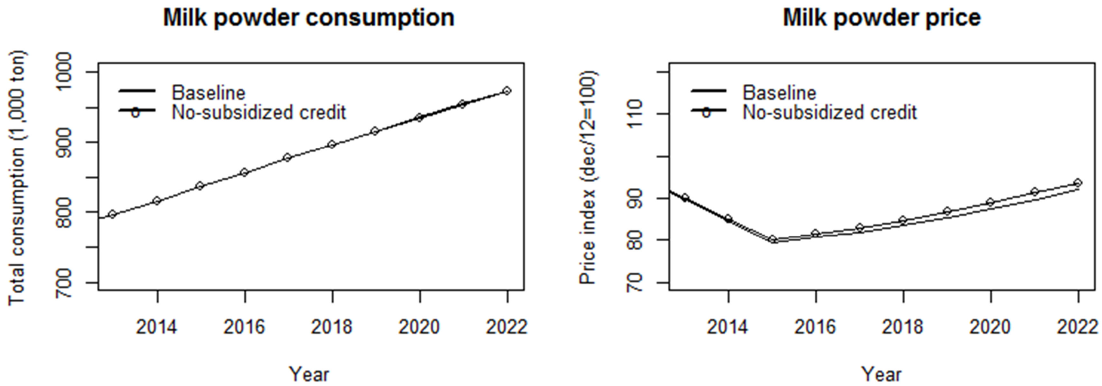

Figure 40. No Subsidized Credit Effects on the Milk Powder Market

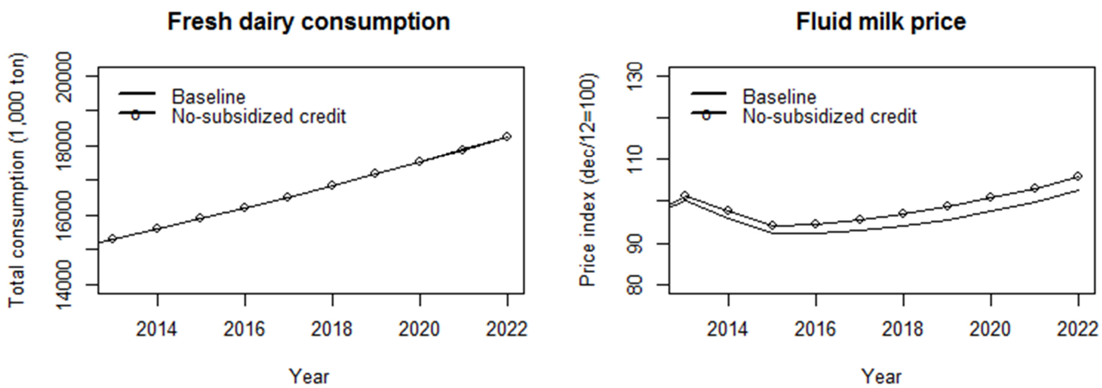

Figure 41. No Subsidized Credit Effects on the Fresh Dairy Market

5.2.3. Minimum Price Guarantee

Another government intervention in the Brazilian dairy market is the price support. Although the price support policy has a long history in the Brazilian grain market, it is relatively new in the case of the dairy market. The minimum milk price policy started in 2005 in Brazil, and since that year the policy has not been used because the price support was consistently set way below the market price.

Theoretically, an increase of milk price support value positively impacts the total milk production. The model incorporates the minimum price through the net revenue variable that affects number of dairy cows and production per cow. Since the current minimum price is very low, the alternative policy consists of increasing the minimum price by 50% over the 2012 level. By doing that, the milk production would increase, on average, by around 1.5% considering the 2013-2022 period (Figure 42). The additional quantity supplied would go up by 0.6 million tons per year, on average. The market price, on the other hand, would decrease by 6% on average due to a higher milk supply.

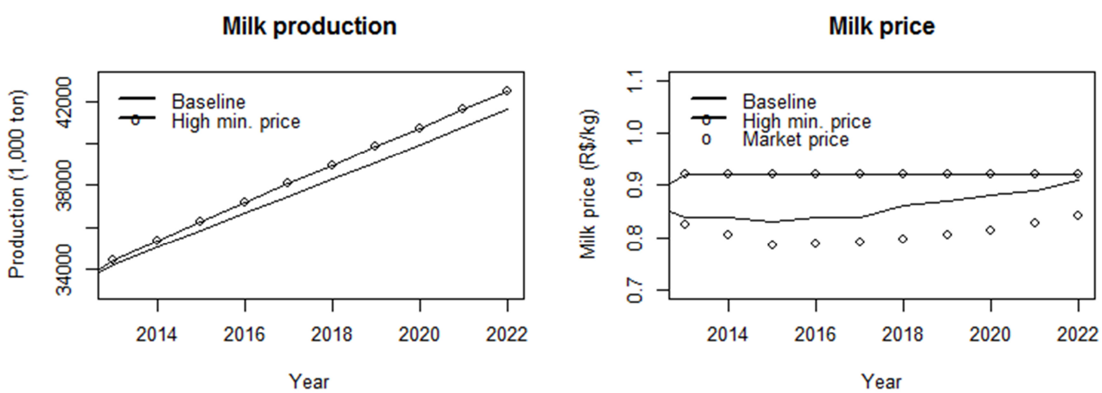

Figure 42. Higher Minimum Milk Price Effects on the Production and Price

Changes in minimum milk price would also have effects on dairy consumption and dairy prices of all products (Figures 43 to 46). Since the total milk production increases with the minimum price, the consumer price has to decrease to reach the supply-demand equilibrium again, all other things constant. Fresh dairy and milk powder prices are relatively more sensitive to changes in the price support. The consumer price for these products would fall off, on average, by 14.4% and 18.0% respectively. Cheese and butter prices would experience only a small reduction.

In terms of consumption, all dairy products would be positively affected by the price support policy. However, the effects of price support on consumption are relatively low. The total consumption would increase, on average, less than 1%.

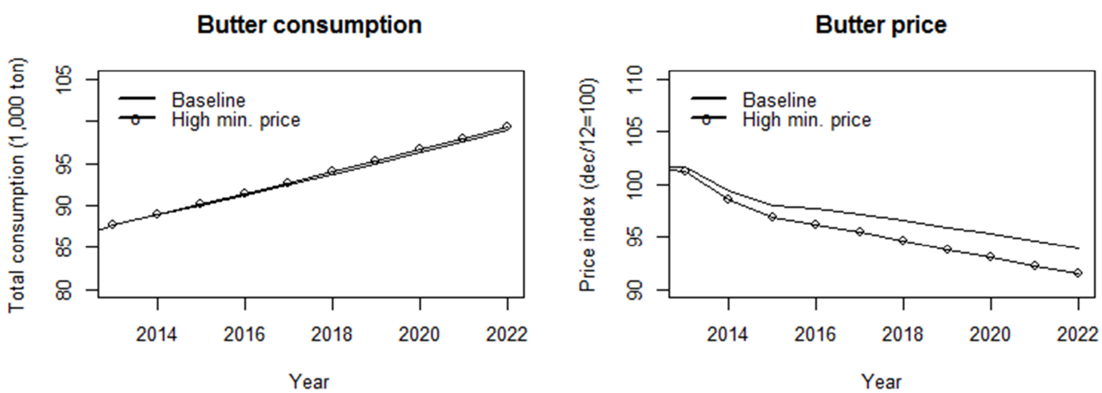

Figure 43. Higher Minimum Milk Price Effects on the Butter Market

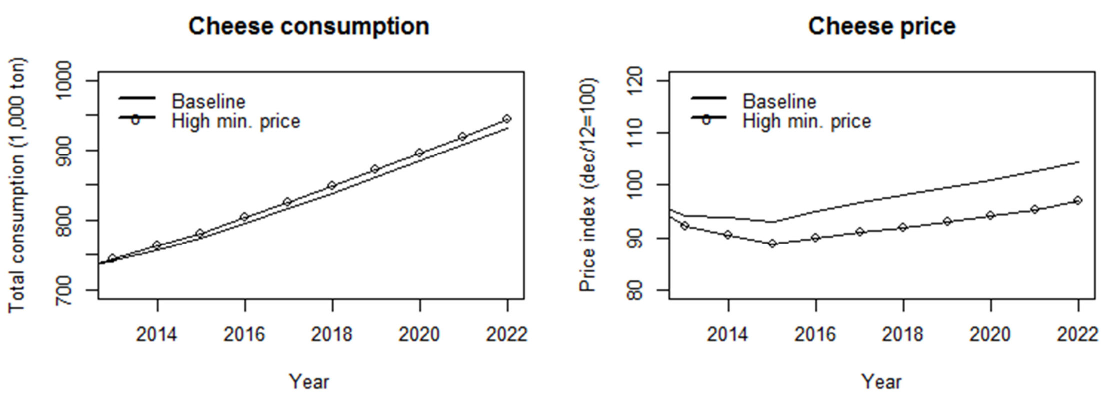

Figure 44. Higher Minimum Milk Price Effects on the Cheese Market

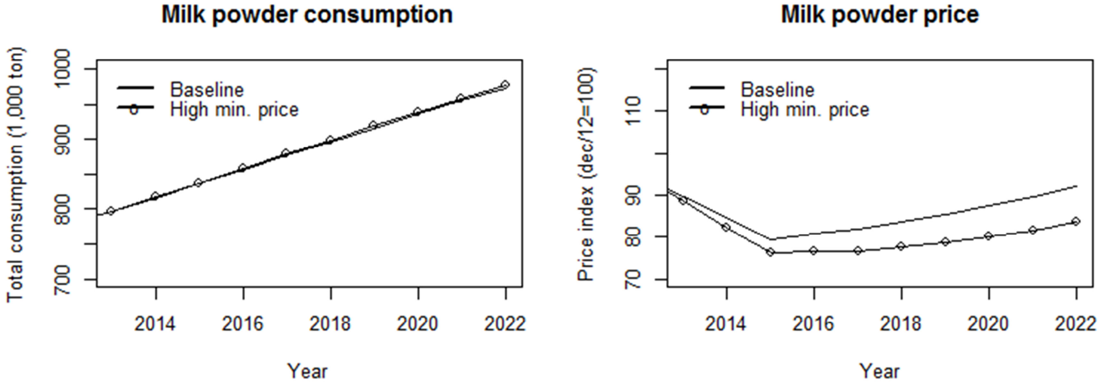

Figure 45. Higher Minimum Milk Price Effects on the Milk Powder Market

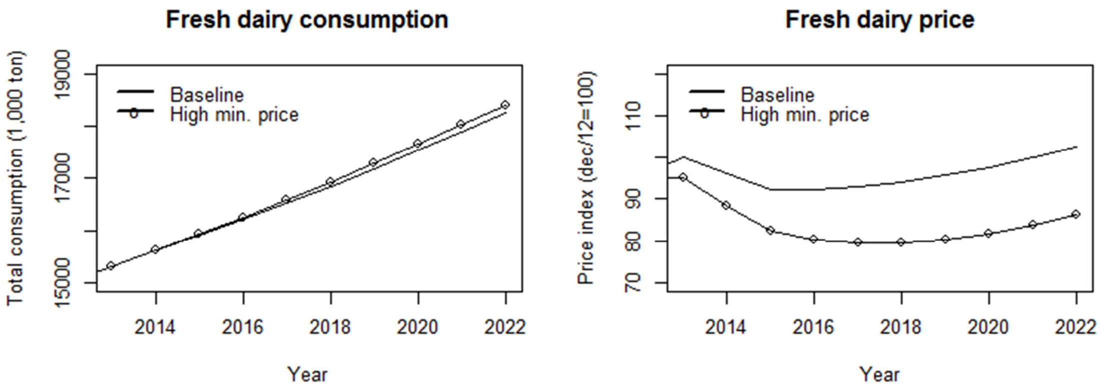

Figure 46. Higher Minimum Milk Price Effects on the Fresh Dairy Market

5.2.4. No-RFS Requirement

The US's RFS regulation, established in 2005, opened up new uses for corn and soybean, which have affected the grain prices as pointed out by Dumortier et al. (2009). The basic hypothesis about the impacts of such a policy is that the RFS requirement positively impacts input prices (corn and soybean) for the dairy sector. Consequently, a negative impact on the Brazilian milk production is expected. The structural model incorporates the RFS policy by connecting the corn and soybean prices in Brazil to the

US corn and soybean prices. Corn and soybean prices in Brazil compose the net revenue variable, and therefore, impacts both number of dairy cows and production per cow. These two equations are used to calculate the total milk production.

In terms of results, the baseline scenario reports a higher feed cost in Brazil (Figure 47). The absence of RFS, on the other hand, would reduce the feed cost compared to the baseline. Actually, the feed cost would be around 5.3 % lower than the baseline cost, on average, considering the 2013-2022 period.

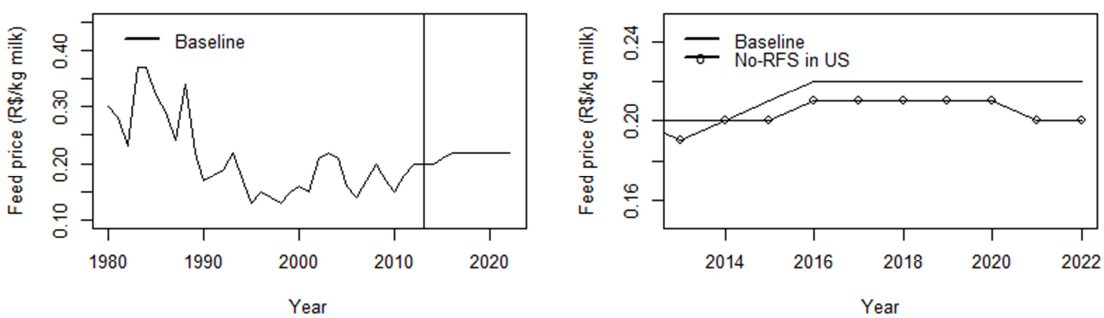

Figure 47. Feed Price in Brazil and the RFS Requirement Effects

The impact of such a change in feed cost, caused by the absence of the RFS requirement, slightly alters both milk production and prices (Figure 48). A possible reason is twofold: first, feed cost is a component of the total cost, and the magnitude of the feed cost variation is not big enough to cause significant changes in the milk production and prices. Second, only the direct effect of RFS requirement on feed cost is accounted for by the dairy model, while the indirect effect, described as the RFS policy impacts on the Brazilian corn and soybean sectors as a whole, is not considered. A more accurate evaluation of the RFS requirement would be possible by integrating the Brazilian dairy model and the Brazilian grain and oilseeds models since those connections would allow feedback.

In the case of dairy consumption and retail prices, the RFS influences are marginal. The small effects of RFS on dairy products are summarized in Figures 49 to 52.

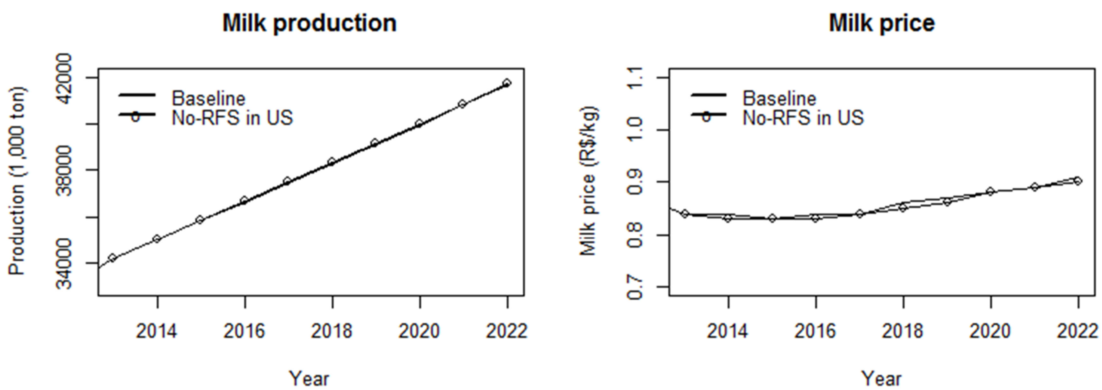

Figure 48. No RFS Requirement Effects on the Milk Production and Price

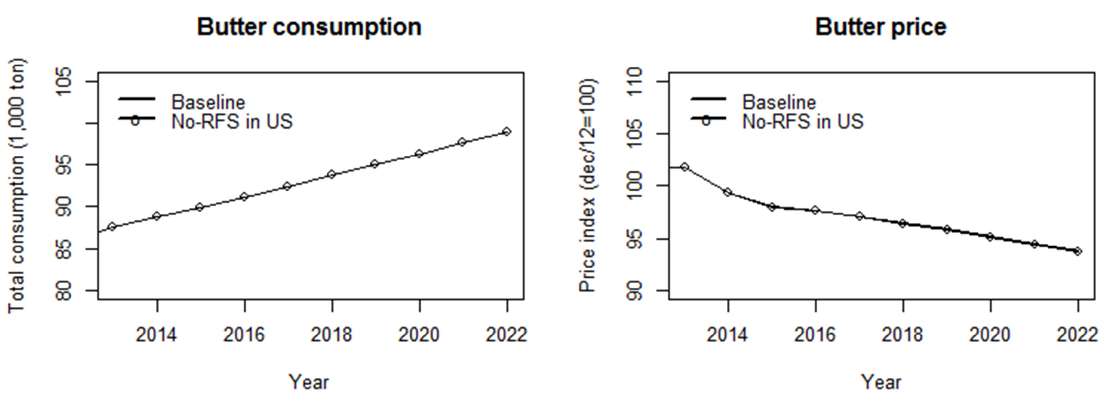

Figure 49. No RFS Requirement Effects on the Butter Market

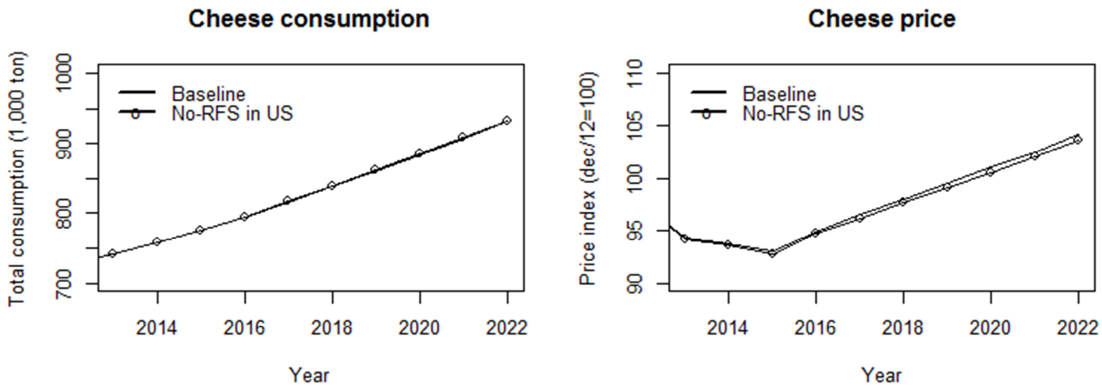

Figure 50. No RFS Requirement Effects on the Cheese Market

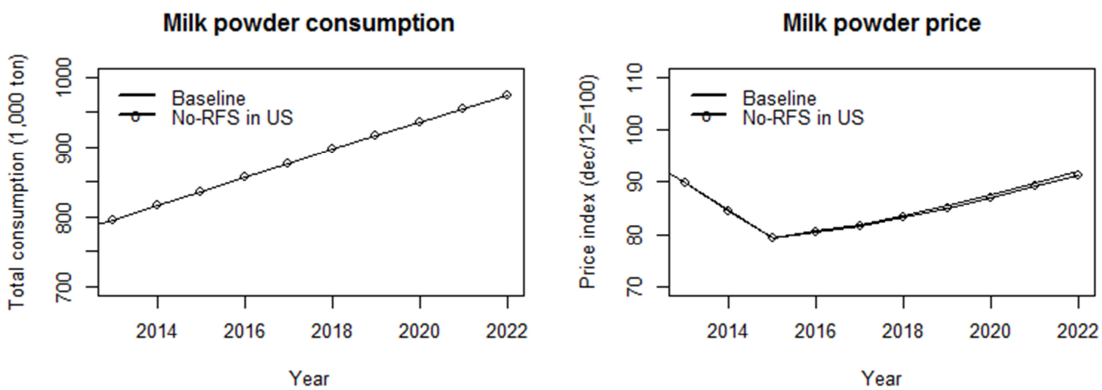

Figure 51. No RFS Requirement Effects on the Milk Powder Market

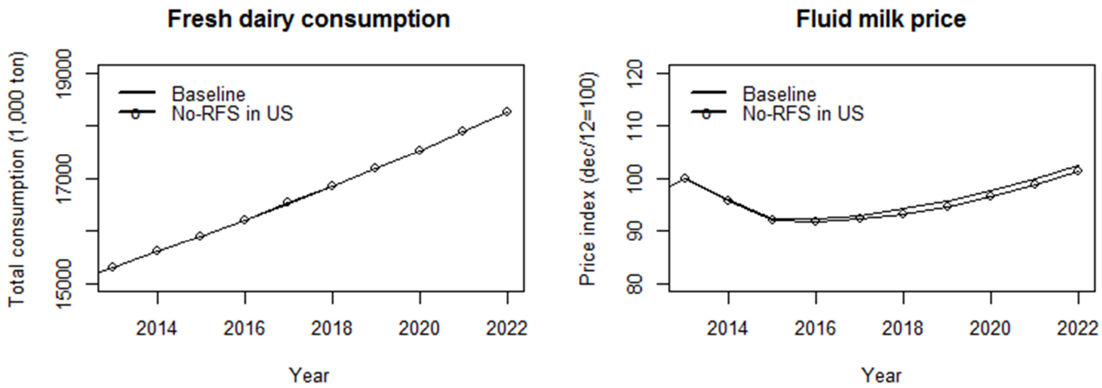

Figure 52. No RFS Requirement Effects on the Fresh Dairy Market

5.2.5. Sugar Cane Expansion

In the case of biofuel policies in Brazil, which have prompted sugar cane acreage expansion, a negative effect on the number of dairy cows is expected. The policy in this case consists of a 30% increasing in sugar cane acreage in *São Paulo* from 2012 to 2022, reaching almost 7 million hectares. Such expansion is based on the Brazilian Ministry of Agriculture forecasts (MAPA, 2013). It is worth remembering that *São Paulo* is the main state in ethanol production, and the growth in sugar cane acreage must negatively affect the milk production in that state (Novo, et al., 2010).

Sugar cane acreage enters into the model through the equation of number of dairy cows. The results indicate that a 30% growth in sugar cane acreage, "*ceteris paribus,*" will decrease the number of dairy cows in *São Paulo* by around 16.5% from 2012 to 2022. Compared to the baseline scenario, the total of dairy cows would drop by 17.6% in 2022 (Figure 53). Similarly, the total milk production in *São Paulo* will decrease by

15.9% compared to the 2012 production. When contrasted with the baseline scenario, the production fall off by 17.5% in 2022.

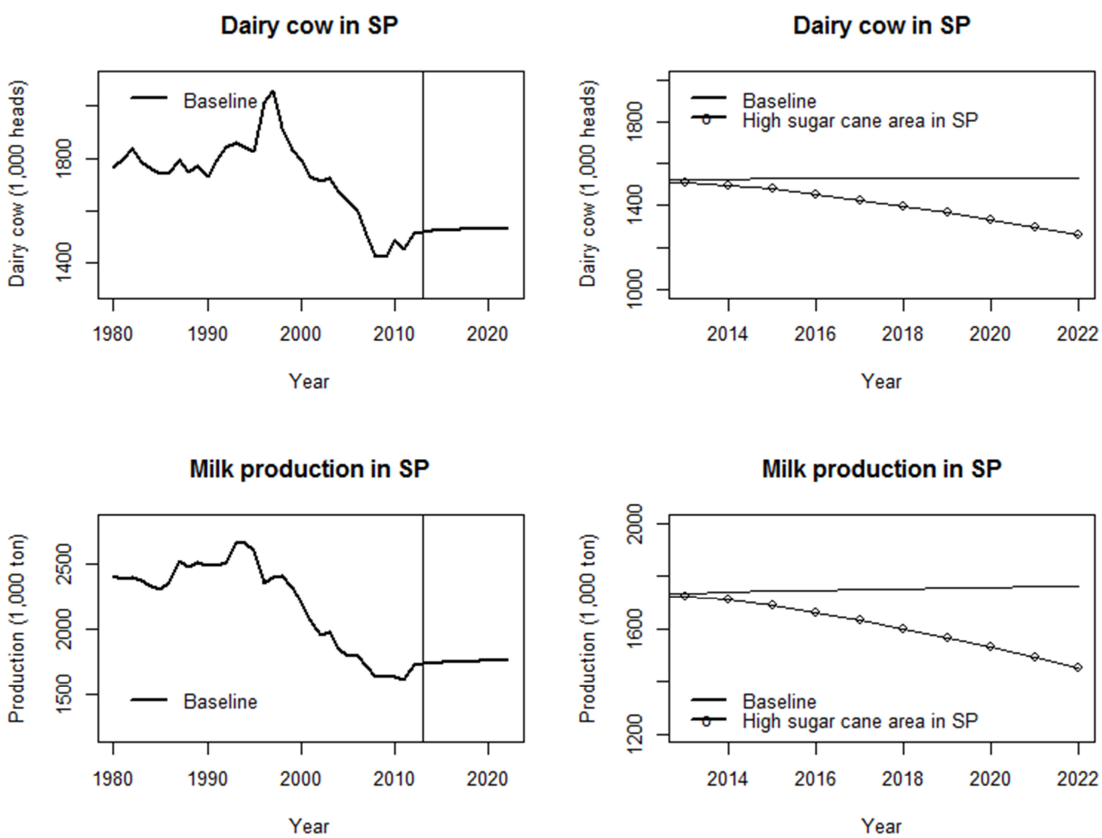

Figure 53. Sugar Cane Expansion Effects on Number of Dairy Cows and Milk Production in São Paulo
Note: Sugar cane acreage increasing 30%, linearly.

Considering the entire country, however, the total milk production is not strongly affected by the sugar cane expansion. This result is expected because historically, the importance of *São Paulo* as a milk supplier has diminished. In the early-1980s the state produced around 15% of the Brazilian milk production. In 2012, on the other hand, the contribution of *São Paulo* was only 5% of the total production. Nevertheless, some effects of the reduction in milk supply are observed in the price level throughout the supply chain. The national farm price is expected to increase around 1%, on average, considering the 2013-2022 period (Figure 54). Dairy prices would also rise as a consequence of the ethanol policy, mainly the cheese and fluid milk prices. The effects on consumer prices would be relatively small, increasing between 1% to 3%, on average (Figures 55 to 58).

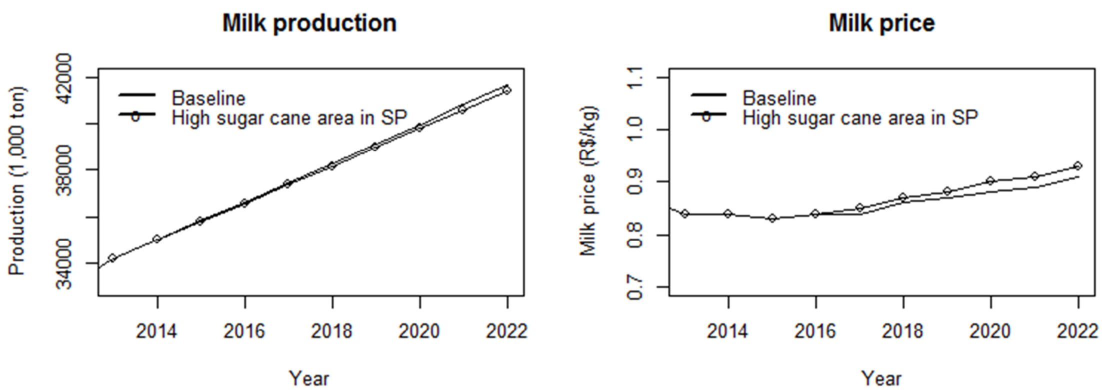

Figure 54. Sugar cane expansion effects on the milk production and price

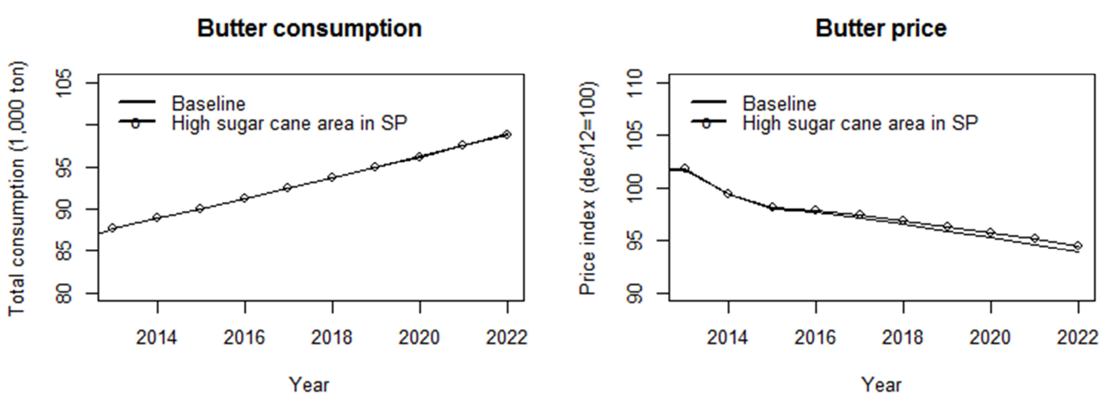

Figure 55. Sugar Cane Expansion Effects on the Butter Market

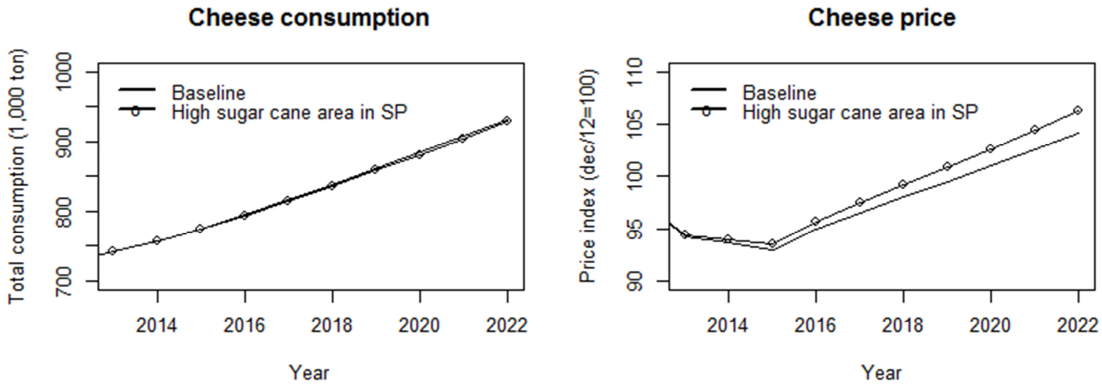

Figure 56. Sugar Cane Expansion Effects on the Cheese Market

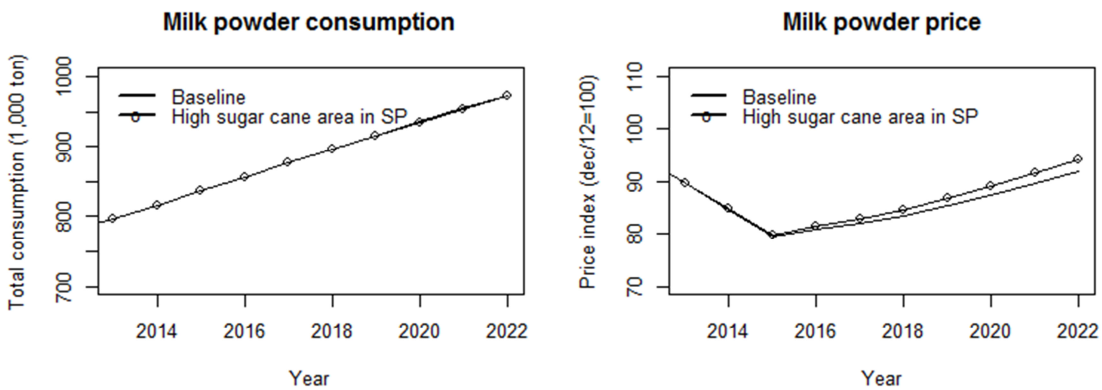

Figure 57. Sugar Cane Expansion Effects on the Milk Powder Market

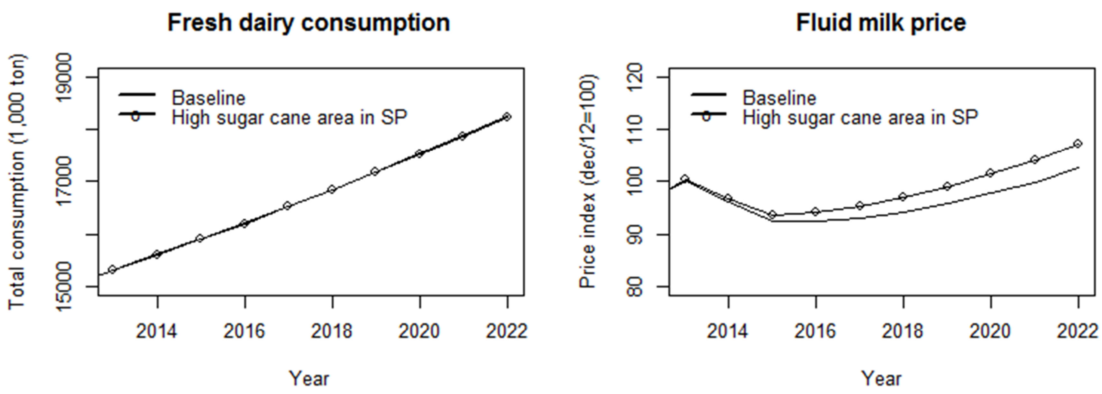

Figure 58. Sugar Cane Expansion Effects on the Fresh Dairy Market

Overall, Brazilian milk production is neither sensitive to changes in the interest rate nor the US's RFS program. On the other hand, some effects are observed when changes in per capita GDP, minimum prices, and sugar cane acreage are considered. However, the impacts are small. The total milk production is positively related to GDP and minimum price, and negatively related to sugar cane acreage. Similar results are found when studying the effects of those shocks on Brazilian milk prices. Again, changes in interest rate and RFS requirement would not have a significant effect on the milk price at the farm level. A higher GDP growth, on the other hand, positively affects milk prices through the demand side of the model. Likewise, high sugar cane acreage in *Sao Paulo* slightly raises milk prices, but in this case by the supply side of the model; that is, the expansion of sugar cane acreage negatively impacts the number of dairy cows and therefore, the milk production.

In summary, the dairy sector in Brazil is not very responsive to changes in exogenous variables. The milk production suffers only marginal changes compared to the baseline scenario. Moreover, shocks from the demand side appear to have greater impacts on milk prices and production. A possible reason is because changes in demand, such as per capita GDP, directly affect the per capita consumption, which is transmitted to prices. In the case of the supply side, farm management in Brazil is not homogenous even between neighboring areas. In addition, many farmers don't know their production cost, which may cause very slow adjustments in the production systems. In other words, since many dairy farms are not professionally managed, the effects of changes in policies and other exogenous variables are not known by those farmers. Consequently, the total production is barely affected by those shocks.

5.3. Welfare Analysis

The main objective of this section is to measure the welfare effects of policy changes on both consumers and producers. For consumers, the welfare analysis is based on the consumer surplus. For producers, on the other hand, the evaluation takes into account the quasirent, as described in Just, et al. (2004).

One of the most frequently used money measurement of the consumer welfare in empirical works is the consumer surplus (S). As for calculation, the consumer surplus is defined as the area under the Marshallian demand curve and above the price line. The consumer surplus is frequently used to measure consumer welfare because the Marshallian demand is often observed. However, the consumer surplus does not exactly provide a measure of gains in utility because it does not measure utility directly. Alternatively, compensating (CV) and equivalent variations (EV) would be an appropriate measure of consumer welfare. For empirical works, however, compensating and equivalent variations are difficult to determine because actual utility levels are not observed.

Figure 59 describes the consumer surplus, compensating and equivalent variations. Consider the initial price decrease from P_0 to P_1 and total consumption moving from q_0 to q_1 over the ordinary demand curve D, for a given income level (m_0). The Hicksian demand curves for both initial and final utility levels are represented by $H(U_0)$ and $H(U_1)$. The consumer surplus change is defined by area *a+b*, and the compensating and equivalent variations are areas *a* and *a+b+c*, respectively. Therefore, if the areas *b* and *c* are negligible, the consumer surplus change can be used as an approximation of compensating and equivalent variations.

For this study, the consumer surplus is considered to be evaluating consumer's welfare changes. The choice is based on the following arguments: 1) the actual utility function is not observed; 2) if the proportion of income spent on the good is small, the changes in consumer surplus, equivalent variation and compensating variation are all very close (Just, et al., 2004). The proportion of expenditure for all dairy products on the average Brazilian family expenditure for all goods is less than 2% (IBGE, 2014), which supports the use of consumer surplus to measure the consumer welfare.

Another limitation of measuring consumer surplus is related to retail price. The model developed in this study solves for four different dairy markets, and the only price available for the entire country is the percentage change in prices, which was used to build the price indexes. To calculate the consumer surplus, the consumer prices for São

Paulo are considered as a proxy for the Brazilian dairy prices. Therefore, the consumer surplus is measured as a sum of the four dairy market's consumer surpluses.

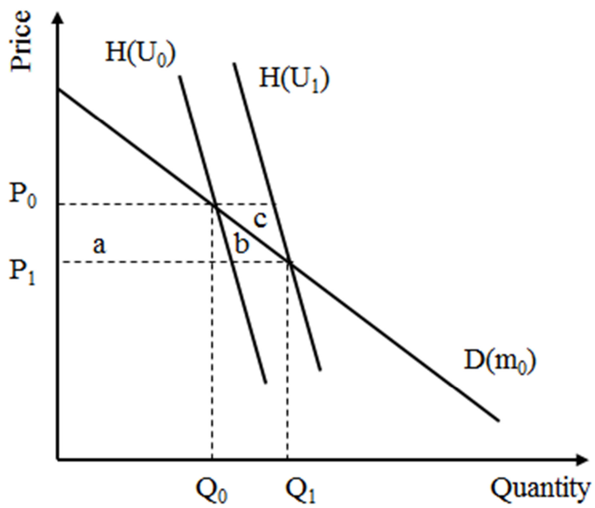

Figure 59. Consumer Surplus, Compensating and Equivalent Variations.
Note: Adapted from Just, et al. (2004)

As for producers, the welfare effect is measured using quasirent (R), which is defined as the excess of gross receipts (TR) over the total variable costs (TVC), that is, R=TR-TVC. Moreover, quasirent is equivalent to producer surplus (P) as pointed out by Just, et al. (2004). Alternatively, profit (π) could be considered to measure the producer surplus. However, one advantage of using quasirent rather than profit to measure welfare is that profit understates the benefits by the fixed cost amount, whereas quasirent does not (Just, et al., 2004). Therefore, both quasirent and producer surplus are given by profit plus total fixed cost (TFC), that is, $R= P= \pi+TFC$.

Measuring the producer welfare effects in the output market is often performed as long as data is available. Alternatively, one could obtain the welfare estimates by looking at the input market. Therefore, the change in quasirent can be completely measured either in the output market or in the input market, as described in Figure 60. Consider a simultaneous change in input (from W_0 to W_1) and output prices (from P_0 to P_1), respectively. Based on the output market, the quasirent is given by area $v+z$ at P_0 and W_0 and by area $x+v$ at prices P_1 and W_1. The change in quasirent is area x-z. The input market surplus, on the other hand, is given by area $e+g$ at prices P_0 and W_0, and by area $e+f$ at prices P_1 and W_1. The change is area f-g, which is equivalent to area x-z in the output market (Just, et al., 2004). The subsequent sections describe details of estimating the welfare change over the 10-year time horizon for each policy change. The evaluation only considers changes in consumer surplus, producer surplus, and government expenditure in the dairy markets.

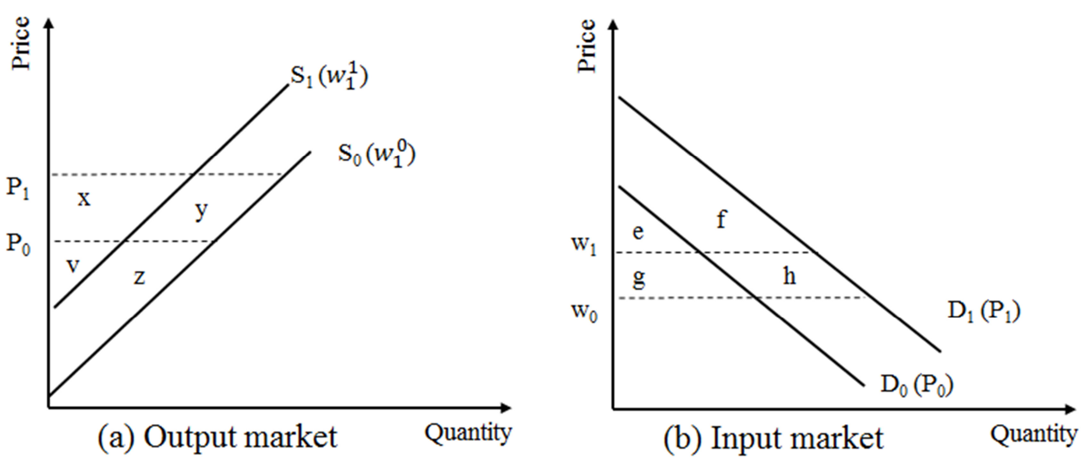

Figure 60. Welfare Measurement in the Output and Input Markets
Note: Adapted from Just, et al. (2004)

5.3.1. No Subsidized Interest Rate

The baseline scenario considers the subsidized interest rate, which affects the variable cost of milk production by the interest cost. As for the alternative scenario, a higher interest rate and interest cost is observed whereas the other costs are held constant. By eliminating the subsidized interest rate policy, the consumers end up paying a higher price for a lower quantity (price P_1 in Figure 61). The consumer surplus is represented by area $a+b+c$ at price P_0 and quantity Q_0 and by area a at price P_1 and quantity Q_1. The consumer welfare is reduced by area $b+c$ in Figure 61. From the producers point of view, the output market producer surplus is represented initially by area $v+z$ at prices P_0 and W_1^0 and $x+v$ at prices P_1 and W_1^1. The change in quasirent is measured as the area x-z.

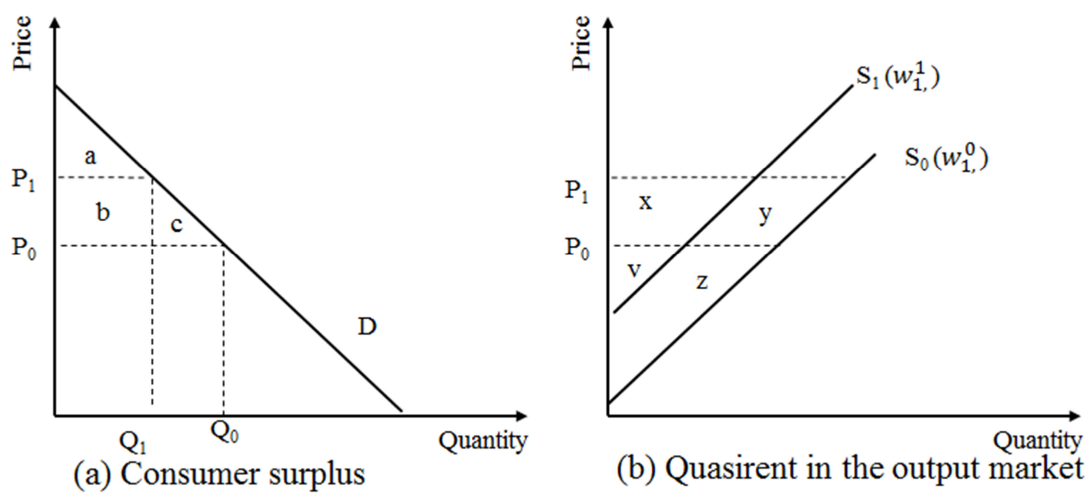

Figure 61. Consumer Surplus and Quasirent: Welfare Effects of a No Subsidized Interest Rate
Note: Adapted from Just, et al. (2004)

The monetary welfare effect on consumers and producers is represented in Table 36. Both consumers and producers would be worse off if the government decides to stop the subsidized interest rate policy. The total loss for producers and consumers over the 10-year forecast is R$7.73 billion and R$13.75 billion, respectively. The government, on the other hand, would be better off due to the reduction in expenditure with the policy change. The total effect, however, indicates loss in welfare of around R$10 billion due to stopping the subsidized interest rate policy.

Table 36. Welfare Effects of No Subsidized Interest Rate, 2013-2022: in Thousand Reais

Year	Change in Quasirent	Change in Consumer Surplus	Change in Government Expenditure	Net Change in Welfare
2013	-857,140	-519,591	1,003,234	-373,497
2014	-829,045	-747,127	1,036,259	-539,913
2015	-812,719	-955,678	1,077,101	-691,295
2016	-793,774	-1,151,760	1,109,408	-836,126
2017	-776,054	-1,333,085	1,138,255	-970,884
2018	-759,476	-1,502,822	1,164,175	-1,098,123
2019	-744,432	-1,662,955	1,188,192	-1,219,195
2020	-731,399	-1,815,258	1,211,380	-1,335,278
2021	-718,887	-1,959,975	1,232,290	-1,446,572
2022	-711,345	-2,100,998	1,256,953	-1,555,390

5.3.2. Minimum Price Guarantee

The minimum milk price policy is another agricultural policy used by the Brazilian government. However, the effect of this policy is not yet observed because the minimum price is set at a very low level. As for policy evaluation, a shock of 50% over the 2012 price level is simulated. The previous result indicates that a high minimum price positively affects the total milk supply and negatively affects the consumer prices.

In terms of welfare effects, both consumers and producers would be better off while the government would face a loss due to higher expenditures to implement the policy.

The consumer surplus is measured by the area *a* at prices P_0 and quantity Q_0 and area $a+b+c$ at price P_1 and quantity Q_1 (Figure 62). The change in consumer welfare is represented by the area $b+c$. In terms of producers, a higher minimum price would stimulate the milk supply and the quasirent would increase by the area *x*. The government, on the other hand, would face a loss in welfare by paying the price difference between the minimum support price and the market price for the total milk production.

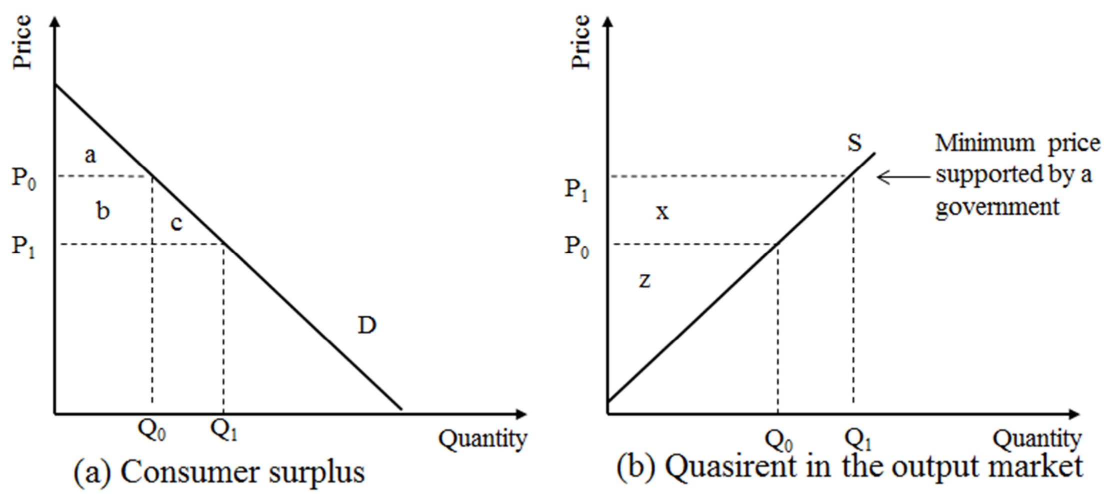

Figure 62. Consumer Surplus and Quasirent: Welfare Effects of High Minimum Price Guarantee

The net effect of the policy is positive as observed in Table 37. The sum of producers and consumers welfare overcomes the loss for the Government. The total net welfare reaches around R$52.8 billion for the 10-year forecast. Moreover, the consumer welfare increases quickly over time because as farmers have an incentive to produce more milk, the negative effect on consumer prices is intensified in the long term. However, a problem with such a policy arises because it tends to decrease the milk price in the long-term, making the producers dependent upon the policy.

Table 37. Welfare Effects of High Minimum Price Guarantee Policy, 2013-2022: in Thousand Reais

Year	Change in Quasirent	Change in Consumer Surplus	Change in Government Expenditure	Net Change in Welfare
2013	3,800,666	2,382,358	-4,473,417	1,709,607
2014	4,225,694	3,782,739	-5,285,385	2,723,047
2015	4,642,686	5,197,850	-6,101,050	3,739,487
2016	4,482,349	6,357,040	-6,251,276	4,588,114
2017	4,256,334	7,379,622	-6,294,094	5,341,862
2018	3,964,517	8,268,651	-6,228,502	6,004,666
2019	3,610,966	9,021,747	-6,058,452	6,574,261
2020	3,190,786	9,630,909	-5,777,696	7,043,999
2021	2,713,259	10,093,634	-5,395,508	7,411,385
2022	2,164,906	10,397,651	-4,898,035	7,664,522

5.3.3. No-RFS Requirement

Another welfare evaluation takes in to account the US's RFS policy, which is considered under the baseline scenario. As for the alternative scenario, assume the RFS program is abolished. As was already discussed in previous sections, removing the RFS program and keeping other things constant would decrease the feed cost, raising the total milk production. The consumers would also face a lower price. In terms of welfare, Figure 63 summarizes the effects of the absence of RFS policy on the Brazilian consumers and producers. The consumer surplus is represented by area a at price P_0 and quantity Q_0 and by area $a+b+c$ at price and quantity P_1 and Q_1, respectively. The change in welfare is positive and it is represented by the area *b+c*. In the case of producers, the analysis is less direct since it involves reduction in both output and input prices. The producer surplus is represented by the area *x+v* at prices P_0 and W_1^0 and by the area *v+z* at prices P_1 and W_1^1. The net effect of the abolishment of the RFS program on the Brazilian producers is, therefore, the area *z-x*.

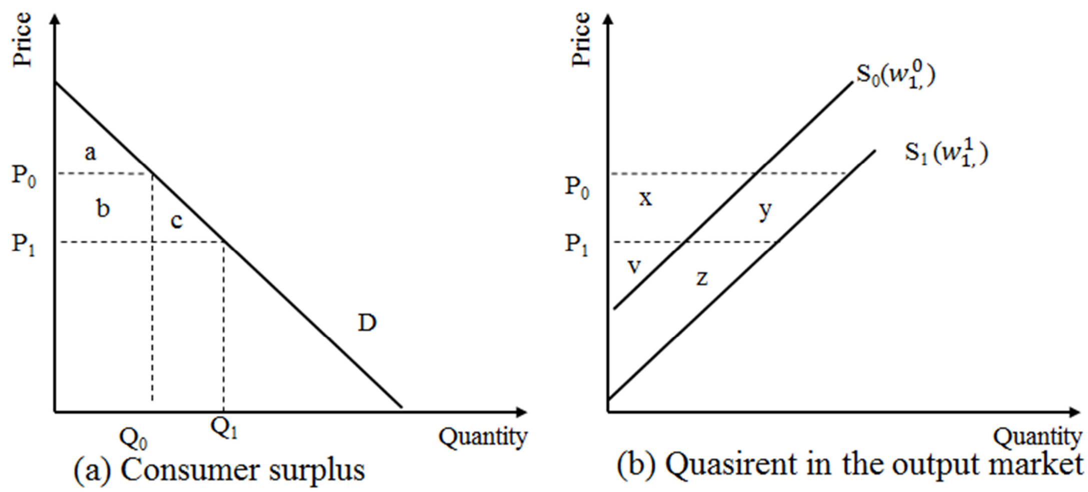

Figure 63. Consumer Surplus and Quasirent: Welfare Effects of No RFS Program in the US

The welfare effect of the absence of RFS policy on consumers is reported in Table 38. Since consumers face a lower price and higher quantity, the change in welfare over the 10-year forecast sums to R$4.5 billion, making them better off. The producers are better off as well and the positive impact on quasirent is explained by the fact that the marginal reduction in milk price is lower than the reduction in feed cost. Therefore, the net effect on the producers is positive. The total welfare effect on both producers and consumers over the 10-year forecast is about R$7.59 billion.

Table 38. Welfare Effects of No RFS Policy in the United States, 2013-2022: in Thousand Reais

Year	Change in Quasirent	Change in Consumer Surplus	Net Change in Welfare
2013	134,706	76,561	211,267
2014	122,540	102,283	224,823
2015	322,036	245,245	567,282
2016	345,946	337,333	683,279
2017	394,140	445,849	839,989
2018	387,923	530,617	918,540
2019	387,759	613,313	1,001,072
2020	362,616	677,716	1,040,332
2021	329,561	728,022	1,057,583
2022	282,302	759,301	1,041,603

5.3.4. Sugar Cane Expansion

The last welfare analysis is relative to sugar cane expansion in *São Paulo*. As previously mentioned, the sugar cane acreage expansion in São Paulo negatively affects the number of dairy cow and total milk production in that state. As a consequence, the consumer price goes up and the total consumption decreases slightly. Therefore, in terms of welfare, the loss in consumer surplus is represented by the area *b+c* in Figure 64. As for producers, the change in welfare carries some interesting facts. First, the expansion of sugar cane does not directly affect the input price, and therefore, the total variable cost is the same under both baseline and alternative scenarios. Moreover, since the expansion occurs only in *São Paulo*, the number of dairy cows (and milk production) decreases in that state but not in the others states. The average national milk price rises slightly and positively affects the producers throughout the country except those located in *São Paulo*. The number of dairy cows is represented by W_2 in Figure 64. The producer surplus is represented by the area *v+z* at prices P_0, $W_1^0$and quantity W_2^0. After the sugar cane acreage expansion, the producer surplus is the area *x+v* at prices P_1, W_1^0 and quantity W_2^1. The change in welfare is measured by the area *x-z*.

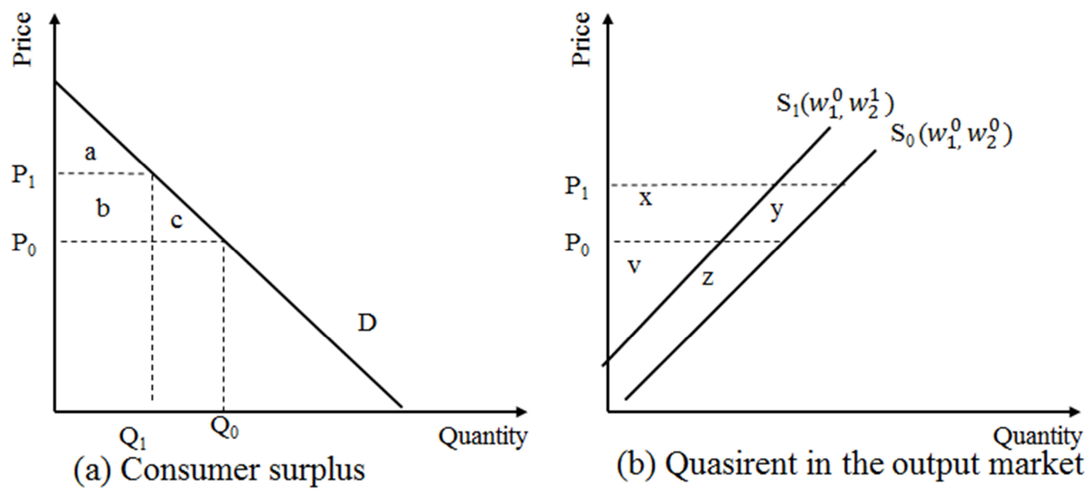

Figure 64. Consumer Surplus and Quasirent: Welfare Effects of Sugar Cane Acreage Expansion in São Paulo

Table 39 summarizes the welfare effect of the sugar cane acreage expansion in *São Paulo*, in thousands of dollars. The consumers, as discussed above, are worse off with such an expansion. The total consumer loss in welfare for the 10-year forecast is about R$14.08 billion. The producers, on the other hand, are better off. In fact, the producers in *São Paulo* are worse off, but a positive spillover effect is observed for the rest of the country; that is, producers in the other states face a higher milk price, which increases the quasirent for the 10-year time horizon to R$3.77 billion. The final change in welfare, however, is negative due to the magnitude of the consumer losses.

Table 39. Welfare Effects of Sugar Cane Acreage Expansion in São Paulo, 2013-2022: in Thousand Reais

Year	Change in Quasirent	Change in Consumer Surplus	Net Change in Welfare
2013	34,761	-123,786	-89,025
2014	91,415	-327,027	-235,611
2015	161,853	-579,541	-417,688
2016	240,318	-868,216	-627,898
2017	323,308	-1,178,626	-855,318
2018	408,764	-1,504,653	-1,095,889
2019	495,571	-1,842,578	-1,347,007
2020	583,196	-2,190,502	-1,607,306
2021	671,281	-2,547,640	-1,876,359
2022	760,408	-2,913,821	-2,153,413

CHAPTER VI

STOCHASTIC ANALYSIS

The last part of this dissertation aims to incorporate risk into the baseline scenario of the Brazilian dairy model, which is represented by the stochastic analysis. By using a stochastic approach for modeling the dairy sector, we are able to estimate the probability distribution of many variables of interest, such as the total milk production and price. Probability appraisal is important not only for estimating the entire probability distribution of some outcome, but also for focusing interest on only the most likely outcome (Reutlinger, 1970).

The stochastic variables considered are production per cow in Brazil, corn and soybean prices in the US and Brazil, and milk prices in Brazil. The milk and feed prices do not have a trend. However, the milk production per cow in each state follows a trend. As pointed out in Richardson (2001), random variables that have a trend can be simulated as a normally distributed variable. Each equation was fitted and the normality of the residuals was tested using both Jarque-Bera and Shapiro-Wilks tests, as discussed in Judge, et al. (1988), and described in Jarque and Bera (1987) and Shapiro and Wilk (1965). The variables themselves are not distributed normally, but the residuals are normal. The null hypotheses of normality were not rejected at the 90% confidence level. The stochastic equations were estimated such that,

$$\tilde{Y}_t = \mu + \beta X_t + \tilde{\varepsilon_t} \qquad (5)$$

where $\widetilde{\varepsilon_t} \sim N(0, \sigma^2)$, which is the probability distribution of the risk about the deterministic component $\mu + \beta X_t$. $\tilde{Y}_t$ represents the group of stochastic variables described above, and X_t is the set of covariates in each equation. Since there is risk in the forecast for Y, the probability distribution should be used to forecast Y rather than using a point estimate (Richardson, 2001). As for simulation, 1,000 realizations were used. The structural procedure for the partial equilibrium model that solves for four dairy markets is the same and consists of minimizing the squared difference of the excess supply in a given year. The only difference from the deterministic model is the inclusion of stochastic components into the dynamic and recursive method. As previously described, the entire model is solved sequentially, one period at a time, for the 10-year forecast.

By considering the production per cow and prices (feed and milk) as stochastic, the majority of the dairy model becomes stochastic as well because other equations are based on the stochastic variables. For example, the net revenue becomes stochastic since both feed and milk prices are stochastic. Therefore, the stochastic net revenue is plugged into the dairy cow and production per cow equations, which makes them also stochastic. Finally, the total milk production is based on the product for number of dairy cows and production per cow, and the total milk production turns stochastic as well. Therefore, the supply side of the model becomes completely stochastic.

Table 40 summarizes the basic statistics for total milk production, which would increase, on average, from 35 million tons in 2014 to 41.7 million tons in 2022. The maximum of milk production would be around 43 million tons in 2022. As can be observed in Table 40, the standard deviation increases over time and implies more risk. However, the total milk production has a stationary coefficient of variation (CV), which means that the relative risk does not increase over time.

In terms of probability, the cumulative distribution function (CDF) of milk production is reported in Figure 65. The estimated numbers for 2022 can be compared with both MAPA and OECD-FAO scenarios. The MAPA scenario is the upper bound production (44.5 million tons), and the probability of occurring is zero. On the other hand, a 100% probability is calculated to achieve the OECD-FAO scenario (38.8 million tons) in 2022. In fact, there is only a 17% probability of milk production being below 38.8 million tons in 2019 already. In other words, the production will be greater than 38.8 million tons in 2019 with 83% probability. As of 2022, the total milk production will be over 41.7 million tons with a 50% probability.

The stochastic results for number of dairy cows and production per cow also suggest an increasing outcome over time and stationary CV. The average number of dairy cows should reach in 2022 about 26.7 million heads (Table 41) with an average of 1,558 kg per cow (Table 42). Therefore, the production per cow will remain at a very low level during the coming years, suggesting that extension programs focused on technological information should be massively stimulated; otherwise the growth of milk production will depend primarily on the expansion of the number of dairy cows.

As for milk price, the stochastic model suggests an average value for the 10-year period of about 80 to 90 cents of *Reais* per kg as described in Table 43. However, the maximum price can exceed R$1/kg, but with low probability. The minimum milk price, on the other hand, is bounded by the minimum price guarantee policy and, therefore, we have a normal probability density function (PDF) truncated from below (Figure 66). The probability of milk price at the minimum is 3.5%, 3.0%, and 0.5% for the 2014, 2018, and 2022, respectively. For the primary endogenous variables (consumer dairy prices), the summary statistics are described in Tables 44 to 47. Overall, the range and the standard deviation of cheese and fluid milk prices are relatively higher than the other two prices.

As for validation, by comparing the deterministic forecasts with the stochastic forecast, it appears the model accurately forecasts the entire system of equations, including the range of minimum and maximum values of each variable as recommended to be checked by Richardson (2001). Moreover, tests for mean and variance were performed between the historical and the simulated residuals. The t-test and F-test was used to verify the null hypothesis of equal means and equal variances respectively, as reported in Tables 48 to 49. Both statistics failed to reject the null hypothesis that means and variances are equals, which suggests that the model accurately simulated the mean and variance for the majority of the random variables.

Finally, there are limitations on the stochastic model that should be pointed. First, the error term is assumed to be independent normal, which either over or understates the risk over time. Moreover, since the correlation matrix is not accounted for in the simulation process, the correlation across simulated random variables may not match the historical data. As mentioned in Richardson (2001), “if two random variables are correlated and their correlation is ignored in simulation, the model will either over or understate the variance and the mean."

Table 40. Summary Statistics of Total Milk Production in Brazil: in 1,000 Ton

Statistics	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Mean	34,221.75	35,046.98	35,862.23	36,664.08	37,517.89	38,328.21	39,162.87	40,005.05	40,828.85	41,671.66
StDev	320.87	340.71	346.58	365.70	363.42	357.65	393.24	394.12	401.59	413.26
CV	0.009	0.010	0.010	0.010	0.010	0.009	0.010	0.010	0.010	0.010
95 % LCI	34,198.97	35,022.80	35,837.63	36,638.12	37,492.09	38,302.83	39,134.95	39,977.07	40,800.34	41,642.33
95 % UCI	34,244.53	35,071.17	35,886.83	36,690.03	37,543.69	38,353.60	39,190.78	40,033.03	40,857.35	41,701.00
Min	33,092.98	34,003.49	34,745.12	35,539.92	36,492.18	37,203.87	37,639.08	38,819.33	39,585.71	40,389.11
Median	34,225.00	35,052.39	35,866.20	36,673.44	37,502.91	38,324.15	39,173.52	39,989.67	40,828.89	41,677.69
Max	35,224.78	36,018.82	36,963.70	37,749.01	38,825.51	39,407.64	40,490.44	41,189.81	42,162.00	43,068.99
Skewness	-0.02	-0.06	-0.11	0.02	0.16	-0.03	-0.04	0.11	0.11	0.00
Kurtosis	0.20	-0.12	-0.17	-0.04	0.05	-0.19	-0.01	-0.09	0.08	-0.04

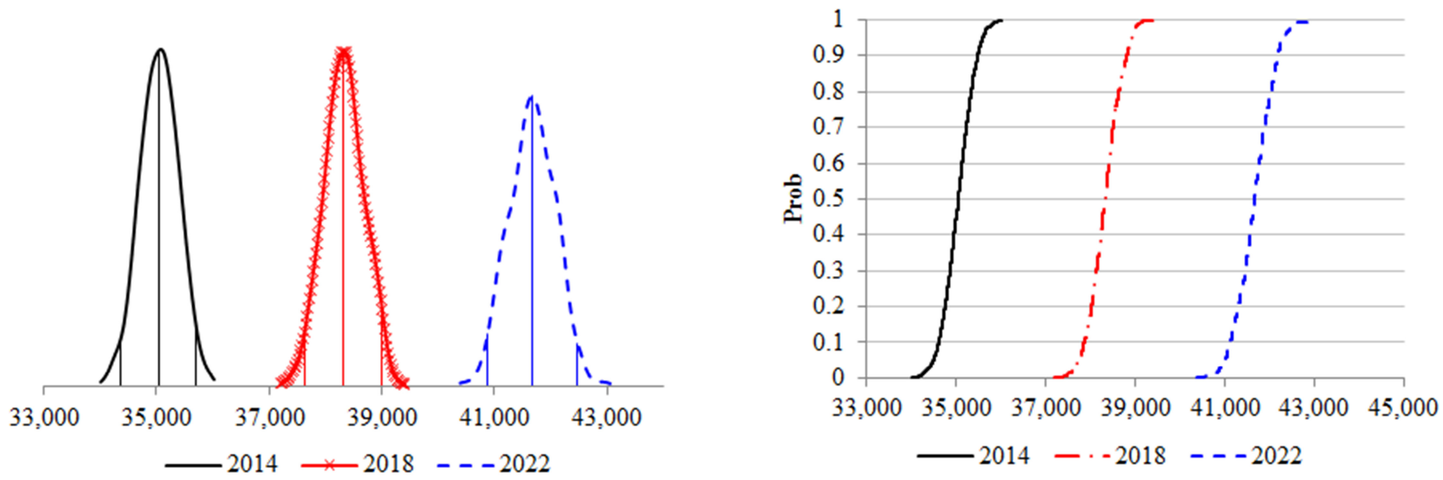

Figure 65. PDF and CDF of Total Milk Production in Brazil

Table 41. Summary Statistics of Number of Dairy Cows in Brazil: in 1,000 Heads.

Statistics	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Mean	23,883.07	24,253.92	24,605.70	24,936.75	25,255.99	25,567.38	25,870.42	26,163.34	26,453.01	26,740.57
StDev	0.00	33.01	42.33	47.79	51.61	55.31	58.50	61.55	64.27	66.85
CV	0.000	0.001	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
95% LCI	23,883.07	24,251.58	24,602.70	24,933.36	25,252.32	25,563.45	25,866.26	26,158.97	26,448.45	26,735.83
95% UCI	23,883.07	24,256.26	24,608.71	24,940.14	25,259.65	25,571.30	25,874.57	26,167.70	26,457.58	26,745.32
Min	23,883.07	24,169.85	24,472.86	24,767.11	25,111.83	25,397.45	25,697.92	25,964.78	26,262.52	26,544.10
Median	23,883.07	24,252.36	24,606.10	24,933.22	25,253.98	25,567.48	25,870.57	26,162.75	26,453.94	26,739.70
Max	23,883.07	24,358.33	24,766.36	25,137.41	25,406.11	25,740.42	26,075.16	26,379.32	26,656.21	26,932.00
Skewness	-1.00	0.22	0.03	0.25	0.11	0.10	0.04	0.07	-0.02	0.02
Kurtosis	-2.00	-0.09	0.15	0.25	-0.35	-0.22	-0.07	0.02	-0.09	-0.03

Table 42. Summary Statistics of Production per Cow in Brazil: in kg.

Statistics	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Mean	1,432.89	1,445.00	1,457.48	1,470.28	1,485.51	1,499.11	1,513.81	1,529.05	1,543.45	1,558.37
StDev	13.44	13.95	13.91	14.56	14.19	13.92	15.01	14.95	15.13	15.55
CV	0.009	0.010	0.010	0.010	0.010	0.009	0.010	0.010	0.010	0.010
95% LCI	1,431.93	1,444.01	1,456.49	1,469.25	1,484.50	1,498.12	1,512.75	1,527.99	1,542.38	1,557.27
95% UCI	1,433.84	1,445.99	1,458.46	1,471.32	1,486.51	1,500.10	1,514.88	1,530.11	1,544.53	1,559.48
Min	1,385.62	1,401.44	1,409.72	1,426.17	1,445.13	1,456.59	1,447.24	1,486.20	1,496.26	1,503.97
Median	1,433.02	1,445.27	1,458.03	1,470.79	1,485.11	1,499.31	1,514.33	1,528.52	1,543.05	1,558.70
Max	1,474.88	1,482.97	1,503.44	1,516.38	1,535.09	1,538.58	1,569.70	1,577.28	1,593.10	1,610.05
Skewness	-0.02	-0.08	-0.11	0.03	0.13	-0.03	-0.06	0.13	0.07	0.00
Kurtosis	0.20	-0.12	-0.08	0.01	-0.01	-0.23	0.21	-0.08	0.05	0.00

Table 43. Summary Statistics of Average Real Milk Price in Brazil: in R$/kg.

Statistics	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Mean	0.84	0.84	0.83	0.83	0.85	0.85	0.86	0.87	0.89	0.91
StDev	0.09	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.09
CV	0.101	0.100	0.099	0.099	0.100	0.098	0.097	0.097	0.095	0.094
95% LCI	0.84	0.83	0.82	0.83	0.84	0.85	0.85	0.87	0.88	0.90
95% UCI	0.85	0.84	0.83	0.84	0.85	0.86	0.86	0.88	0.90	0.91
Min	0.62	0.67	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69
Median	0.84	0.84	0.82	0.83	0.85	0.85	0.86	0.87	0.89	0.91
Max	1.14	1.14	1.15	1.11	1.13	1.16	1.12	1.13	1.20	1.20
Skewness	0.12	0.06	0.22	0.25	0.10	0.15	0.10	0.02	0.09	-0.02
Kurtosis	0.13	-0.30	-0.37	-0.34	-0.35	-0.25	-0.20	-0.33	0.08	-0.13

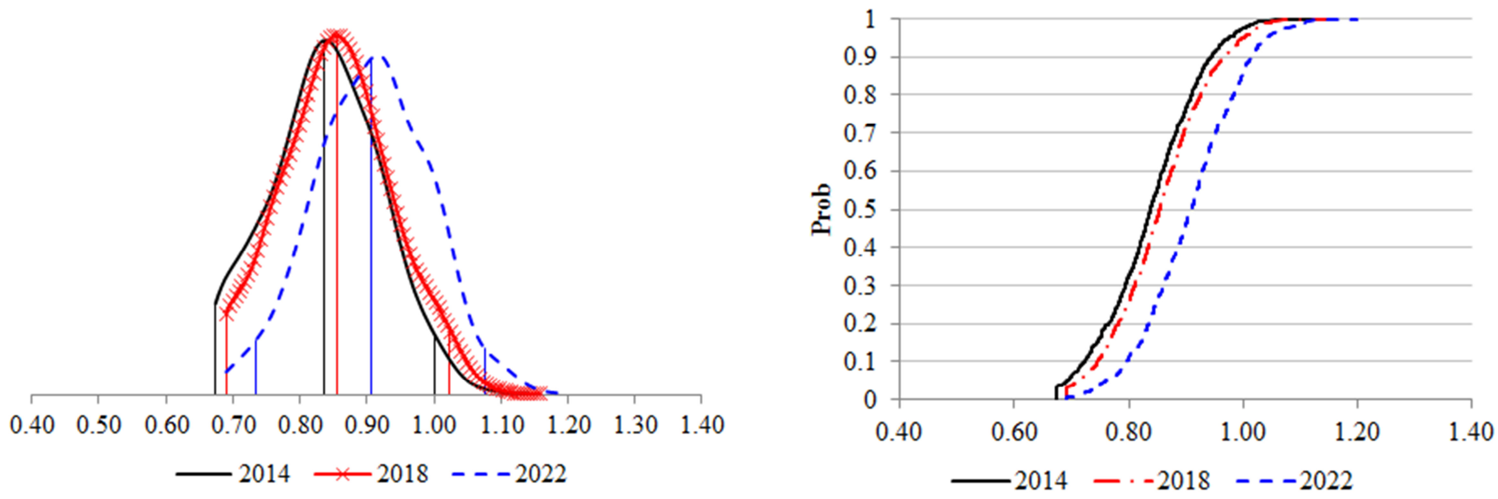

Figure 66. PDF and CDF of Deflated Milk Price in Brazil

Table 44. Summary Statistics: Butter Price Index

Statistics	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Mean	101.74	99.38	97.99	97.64	97.00	96.42	95.79	95.12	94.48	93.81
StDev	0.83	0.88	0.90	0.96	0.95	0.93	1.01	1.02	1.03	1.05
CV	0.008	0.009	0.009	0.010	0.010	0.010	0.011	0.011	0.011	0.011
95% LCI	101.68	99.32	97.92	97.57	96.93	96.36	95.71	95.04	94.41	93.74
95% UCI	101.80	99.45	98.05	97.70	97.07	96.49	95.86	95.19	94.56	93.89
Min	99.16	96.75	95.19	94.85	93.33	93.57	92.42	92.28	91.21	90.28
Median	101.73	99.36	97.97	97.63	97.04	96.44	95.76	95.13	94.49	93.82
Max	104.66	101.94	100.99	100.50	99.92	99.25	99.63	98.49	97.73	97.12
Skewness	0.02	0.05	0.10	-0.03	-0.15	0.01	0.05	-0.07	-0.10	-0.01
Kurtosis	0.20	-0.10	-0.19	-0.07	0.10	-0.22	-0.02	-0.11	0.05	0.02

Table 45. Summary Statistics: Cheese Price Index

Statistics	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Mean	94.36	93.79	92.86	94.91	96.10	97.72	99.14	100.57	102.35	104.10
StDev	3.56	3.72	3.70	3.87	3.78	3.70	4.05	4.01	4.06	4.16
CV	0.038	0.040	0.040	0.041	0.039	0.038	0.041	0.040	0.040	0.040
95% LCI	94.10	93.52	92.60	94.64	95.84	97.46	98.85	100.29	102.06	103.80
95% UCI	94.61	94.05	93.13	95.19	96.37	97.98	99.42	100.86	102.64	104.39
Min	83.72	83.85	81.84	83.56	83.74	86.80	86.17	88.77	89.64	90.97
Median	94.26	93.70	92.74	94.75	96.15	97.72	98.90	100.70	102.33	104.01
Max	107.51	105.86	104.90	107.29	107.11	110.18	115.82	112.66	115.47	117.90
Skewness	0.12	0.16	0.19	0.09	-0.06	0.12	0.13	-0.02	0.00	0.11
Kurtosis	0.23	-0.08	-0.13	-0.03	-0.03	-0.13	0.01	-0.10	0.06	-0.07

Table 46. Summary Statistics: Milk Powder Price Index

Statistics	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Mean	89.72	84.63	79.33	80.73	81.69	83.20	85.00	87.00	89.29	91.62
StDev	2.01	2.19	2.23	2.44	2.52	2.54	2.74	2.83	2.93	3.04
CV	0.022	0.026	0.028	0.030	0.031	0.031	0.032	0.033	0.033	0.033
95% LCI	89.58	84.48	79.18	80.56	81.51	83.02	84.80	86.80	89.09	91.41
95% UCI	89.87	84.79	79.49	80.91	81.86	83.38	85.19	87.20	89.50	91.84
Min	83.51	77.99	72.65	73.43	71.56	76.16	76.08	78.89	80.03	81.78
Median	89.70	84.59	79.35	80.77	81.77	83.27	84.97	86.96	89.40	91.58
Max	96.91	91.32	87.17	87.79	89.56	90.58	94.82	96.89	98.62	101.73
Skewness	0.04	0.05	0.10	-0.02	-0.08	0.01	0.10	0.00	-0.07	0.01
Kurtosis	0.20	-0.06	-0.20	-0.13	0.09	-0.25	-0.04	-0.14	-0.01	0.03

Table 47. Summary Statistics: Fluid Milk Price Index

Statistics	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Mean	100.13	96.05	91.97	92.18	91.76	93.23	94.64	96.47	99.35	102.19
StDev	8.52	9.01	9.09	9.46	9.28	9.03	9.89	9.78	9.85	10.06
CV	0.085	0.094	0.099	0.103	0.101	0.097	0.105	0.101	0.099	0.098
95% LCI	99.53	95.41	91.32	91.51	91.10	92.58	93.93	95.78	98.65	101.48
95% UCI	100.74	96.69	92.62	92.85	92.42	93.87	95.34	97.17	100.05	102.90
Min	73.51	71.04	63.55	62.68	59.46	65.13	61.02	65.64	66.43	68.82
Median	100.04	96.00	91.88	92.00	91.99	93.30	94.19	96.87	99.45	102.20
Max	130.10	124.10	120.15	121.03	117.59	122.77	132.78	124.09	129.71	133.91
Skewness	0.02	0.07	0.10	-0.01	-0.16	0.04	0.01	-0.12	-0.09	0.02
Kurtosis	0.20	-0.12	-0.18	-0.04	0.03	-0.17	-0.03	-0.08	0.05	-0.08

Table 48. Two Sample t-test on Null Hypothesis of Equal Means between Historical and Simulate Residuals at the 95% Confidence Level

Stochastic variables	2013		2022	
	P-value	Decision	P-value	Decision
Milk production per cow				
Goiás	1.00	F	1.00	F
Minas Gerais	1.00	F	1.00	F
São Paulo	1.00	F	1.00	F
Paraná	1.00	F	1.00	F
Santa Catarina	1.00	F	1.00	F
Rio Grande do Sul	1.00	F	1.00	F
Other States	1.00	F	1.00	F
Brazilian Milk price	1.00	F	1.00	F
Brazilian Corn price	1.00	F	1.00	F
Brazilian Soybean price	1.00	F	1.00	F
US Corn price	0.98	F	0.98	F
US Soybean price	0.99	F	0.99	F

Table 49. F test on Null Hypothesis of Equal Variances between Historical and Simulate Residuals at the 95% Confidence Level

Stochastic variables	2013		2022	
	P-value	Decision	P-value	Decision
Milk production per cow				
Goiás	0.19	F	0.00	R
Minas Gerais	0.27	F	0.31	F
São Paulo	0.31	F	0.34	F
Paraná	0.41	F	0.38	F
Santa Catarina	0.30	F	0.43	F
Rio Grande do Sul	0.36	F	0.25	F
Other States	0.32	F	0.41	F
Brazilian Milk price	0.37	F	0.37	F
Brazilian Corn price	0.27	F	0.34	F
Brazilian Soybean price	0.02	R	0.01	R
US Corn price	0.45	F	0.40	F
US Soybean price	0.40	F	0.47	F

CHAPTER VII

CONCLUSIONS

The study presented has many important characteristics that contribute to policy makers and private companies understanding the Brazilian dairy industry. The findings may also provide support for future research in the industry. This is the first model developed for the Brazilian dairy sector that allows for policy analysis, measuring effects of policy changes and other variables of interest on production, consumption, and milk prices.

The 10-year forecasts provide important insights in terms of trends. Moreover, the behavior of numerous groups of variables under the *status quo* of relevant policies and key variables related to the Brazilian dairy sector was studied and measured. By using the determinist approach, the model can also give feedback when changes in the base scenario are considered. Important shocks were evaluated in the demand and supply side of the model. Changes in important variables, such as GDP, sugar cane acreage, US RFS requirement, interest rate, and minimum milk price, were considered and the effects on the entire system of equations were measured. The forecast itself can offer relevant references for decision makers. However, the model should not be used to only identify the forecast levels of key output variables. Using the model to measure the effects in the current scenario to policy changes is much more relevant. Equally important, the approach developed here helps to identify the sensitivity of the entire system of equations to changes in specific variables. Those are the major contributions of this research to the Brazilian dairy sector.

Another innovation of the research is the inclusion of a stochastic framework in a sector level structural equation model. By incorporating risk, the entire probability of outcomes can be evaluated instead of only a point estimates. The evaluation of different shocks considering the stochastic approach, however, was not performed to avoid repetition. Nevertheless, the actual structural model can and will be used for conducting future studies and policy analyses of the sector. All of the work spent to build this model is expected to derive numerous projects to further develop the Brazilian dairy sector and society will reap the benefits.

Models are just a tentative representation of the real word. Limitations are very common in the modelling procedure, and numerous restrictions were encountered in this research. Because of data constraints, many sources had to be merged, generating problems in balancing supply, demand, and price. Some data are also published with two years delay, causing difficulties to incorporate up to date information. Another limitation of the model was related to data aggregations. The dairy sector is composed of a wide variety of products that are produced from raw milk, but data are not available for most of the products. The model was built to solve for four dairy markets: butter, cheese, milk powder, and fresh products. The fresh market, however, represents a group of products, which generates drawback in terms of conversions, elasticities, and consumer preferences. If more milk prices and costs components were available, the supply side of the model could also incorporate more Brazilian States and not only the top six as considered in this research. The final limitation in terms of data refers to the inexistence of wholesale level information that penalizes a more detailed evaluation throughout the supply chain.

In terms of model structure, the integration of other agricultural models, such as corn, soybean, and livestock, would allow feedback to improve the structure and the ability of the model. These were treated as exogenous with respect to the dairy model. As for the stochastic analysis, the main limitation refers to the assumption of independence between random variables, which is not the preferred assumption.

Regarding the limitations described above, the model appears to perform well in representing the actual sector. The milk production forecasts are reasonable. The dairy sector is more sensitive to shocks from the demand side than from the supply side, which must be a result of heterogeneous production systems and naive average farm management in Brazil. The entire system of equations is estimated based on economic relationships between variables. Moreover, the classical statistical and regression assumptions are considered by the econometric procedures. The dairy industry is very dynamic and will continue to change over time. As change occurs, the model will need to be updated to incorporate new information.

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APPENDIX

Table A-1. Selected Exogenous Variables under the Baseline Scenario.

Variable	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Real GDP growth rate (%)	2.49	1.73	1.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50
Nominal interest rate in GO (%)	3.49	3.49	3.49	3.49	3.49	3.49	3.49	3.49	3.49	3.49
Nominal interest rate in MG (%)	4.83	4.83	4.83	4.83	4.83	4.83	4.83	4.83	4.83	4.83
Nominal interest rate in SP (%)	3.37	3.37	3.37	3.37	3.37	3.37	3.37	3.37	3.37	3.37
Nominal interest rate in PR (%)	3.17	3.17	3.17	3.17	3.17	3.17	3.17	3.17	3.17	3.17
Nominal interest rate in SC (%)	2.80	2.80	2.80	2.80	2.80	2.80	2.80	2.80	2.80	2.80
Nominal interest rate in RS (%)	2.51	2.51	2.51	2.51	2.51	2.51	2.51	2.51	2.51	2.51
Nominal interest rate in OT (%)	3.22	3.22	3.22	3.22	3.22	3.22	3.22	3.22	3.22	3.22
Minimum milk price in GO, and OT (R$/kg)	0.62	0.67	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69
Minimum milk price in MG, SP, PR, SC, RS (R$/kg)	0.64	0.69	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71
Corn price in US (US$/bushel)	5.73	5.72	5.92	5.69	5.56	5.36	5.18	4.98	4.78	4.74
Soybean price in US (US$/bushel)	14.64	15.97	16.73	17.28	17.33	17.27	17.07	16.77	16.41	16.00
Sugar cane acreage (1,000 Ha)	5,150	5,150	5,150	5,150	5,150	5,150	5,150	5,150	5,150	5,150

Note: GO = Goiás; MG = Minas Gerais; SP = São Paulo; PR = Paraná; SC = Santa Catarina; RS = Rio Grande do Sul;

OT = Other states

Table A-2. Number of Dairy Cows, Production per Cow, Total Production and Milk Price per State: Baseline Scenario

	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Goiás										
Dairy cow	2,789.47	2,803.70	2,816.40	2,827.52	2,837.90	2,847.72	2,857.12	2,866.22	2,875.09	2,883.83
Production per cow	1,313.70	1,317.48	1,319.55	1,321.76	1,324.48	1,327.96	1,332.42	1,337.97	1,344.80	1,352.79
Milk production	3,664.53	3,693.83	3,716.36	3,737.32	3,758.74	3,781.67	3,806.87	3,834.91	3,866.41	3,901.21
Milk price	0.73	0.72	0.71	0.72	0.73	0.73	0.74	0.75	0.76	0.78
Minas Gerais										
Dairy cow	5,963.89	6,078.84	6,189.44	6,295.68	6,398.52	6,498.22	6,595.00	6,689.06	6,780.55	6,869.64
Production per cow	1,593.87	1,602.98	1,612.03	1,621.36	1,630.74	1,640.16	1,649.62	1,659.09	1,668.60	1,678.09
Milk production	9,505.69	9,744.25	9,977.56	10,207.55	10,434.32	10,658.13	10,879.22	11,097.77	11,314.00	11,527.87
Milk price	0.84	0.84	0.83	0.84	0.84	0.85	0.87	0.88	0.89	0.91
São Paulo										
Dairy cow	1,520.90	1,524.84	1,527.26	1,528.59	1,529.52	1,530.24	1,530.88	1,531.49	1,532.11	1,532.78
Production per cow	1,140.28	1,141.13	1,141.84	1,142.99	1,144.19	1,145.43	1,146.71	1,147.99	1,149.30	1,150.57
Milk production	1,734.26	1,740.04	1,743.88	1,747.15	1,750.05	1,752.79	1,755.47	1,758.14	1,760.86	1,763.57
Milk price	0.83	0.82	0.82	0.82	0.83	0.84	0.85	0.87	0.88	0.89

Table A-2. Continued

	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Paraná										
Dairy cow	1,710.45	1,756.79	1,802.71	1,848.16	1,893.32	1,938.24	1,982.94	2,027.45	2,071.77	2,115.92
Production per cow	2,410.86	2,441.27	2,470.86	2,504.62	2,539.11	2,574.21	2,609.75	2,645.63	2,681.93	2,718.07
Milk production	4,123.65	4,288.81	4,454.24	4,628.94	4,807.36	4,989.43	5,174.99	5,363.87	5,556.32	5,751.22
Milk price	0.79	0.78	0.77	0.78	0.79	0.80	0.81	0.82	0.84	0.85
Santa Catarina										
Dairy cow	1,167.06	1,222.09	1,276.78	1,331.01	1,385.31	1,439.73	1,494.36	1,549.24	1,604.41	1,659.92
Production per cow	2,568.48	2,603.79	2,638.78	2,675.56	2,712.62	2,749.92	2,787.39	2,825.01	2,862.80	2,900.53
Milk production	2,997.57	3,182.08	3,369.13	3,561.21	3,757.80	3,959.14	4,165.37	4,376.62	4,593.11	4,814.65
Milk price	0.74	0.73	0.72	0.73	0.74	0.75	0.76	0.78	0.79	0.81
Rio Grande do Sul										
Dairy cow	1,588.25	1,612.81	1,636.55	1,659.42	1,681.88	1,704.00	1,725.85	1,747.47	1,768.91	1,790.22
Production per cow	2,572.31	2,598.31	2,623.66	2,652.72	2,682.31	2,712.40	2,742.85	2,773.58	2,804.66	2,835.64
Milk production	4,085.47	4,190.57	4,293.75	4,401.97	4,511.32	4,621.92	4,733.74	4,846.76	4,961.21	5,076.41
Milk price	0.75	0.74	0.73	0.74	0.75	0.76	0.78	0.79	0.81	0.83

Table A-2. Continued

	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Outros										
Dairy cow	9,143.06	9,254.38	9,354.09	9,441.95	9,524.06	9,601.66	9,675.84	9,747.41	9,816.97	9,885.17
Production per cow	887.43	886.91	886.15	886.54	887.10	887.83	888.68	889.61	890.66	891.65
Milk production	8,113.83	8,207.85	8,289.12	8,370.64	8,448.84	8,524.69	8,598.73	8,671.42	8,743.54	8,814.08
Brazil										
Dairy cow	23,883.07	24,253.46	24,603.22	24,932.33	25,250.50	25,559.80	25,861.99	26,158.34	26,449.82	26,737.49
Production per cow	1,433.02	1,445.05	1,456.88	1,470.17	1,483.87	1,497.97	1,512.43	1,527.22	1,542.37	1,557.70
Milk production	34,225.00	35,047.43	35,844.04	36,654.78	37,468.42	38,287.78	39,114.40	39,949.49	40,795.45	41,649.00
Milk price	0.84	0.84	0.83	0.84	0.84	0.86	0.87	0.88	0.89	0.91

Note: milk production in 1,000 metric tons; dairy cow in 1,000 heads; Production per cow in kg; Milk price in *Reais* per kg.

Table A-3. Dairy Market and Trade: Baseline Scenario

	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Butter Market										
Production	84.08	85.93	87.29	88.67	90.02	91.38	92.75	94.14	95.53	96.94
Import	4.00	3.47	3.19	3.06	2.98	2.90	2.82	2.74	2.65	2.56
Export	0.45	0.52	0.55	0.55	0.56	0.56	0.57	0.57	0.58	0.58
Consumption	87.62	88.88	89.93	91.17	92.44	93.72	95.01	96.30	97.61	98.93
Price	101.73	99.38	98.03	97.67	97.13	96.54	95.93	95.28	94.59	93.88
Cheese Market										
Production	721.63	742.68	762.98	784.90	806.74	828.67	850.78	873.12	895.75	918.64
Import	22.46	17.54	14.04	12.31	11.66	11.68	12.15	12.93	13.92	15.07
Export	2.42	2.30	2.24	2.23	2.23	2.25	2.27	2.29	2.32	2.36
Consumption	741.67	757.93	774.78	794.99	816.16	838.11	860.66	883.75	907.35	931.35
Price	94.26	93.73	93.00	94.95	96.56	98.06	99.54	101.04	102.57	104.20
Milk Powder Market										
Production	720.99	748.16	771.74	793.67	814.22	833.78	852.67	871.13	889.34	907.39
Import	79.66	74.55	70.93	69.75	69.55	69.89	70.54	71.38	72.34	73.36
Export	4.78	6.05	6.59	6.83	6.97	7.06	7.10	7.14	7.19	7.24
Consumption	795.87	816.66	836.08	856.58	876.80	896.61	916.11	935.37	954.49	973.50
Price	89.70	84.61	79.43	80.81	82.00	83.56	85.42	87.51	89.71	91.94

Table A-3. Continued

	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Fresh Dairy Market										
Production	15,291.80	15,588.82	15,881.51	16,188.15	16,506.73	16,835.83	17,174.34	17,521.65	17,877.32	18,240.67
Import	19.74	21.11	20.61	19.32	17.80	16.34	15.15	14.09	13.02	12.00
Export	0.04	0.04	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Consumption	15,311.49	15,609.89	15,902.07	16,207.42	16,524.48	16,852.12	17,189.44	17,535.68	17,890.29	18,252.61
Price	100.04	96.05	92.45	92.39	93.01	94.15	95.72	97.68	99.93	102.49

Notes: production in 1,000 metric tons; Price index Dec/2012=100

Table A-4. Selected Exogenous Variables under Alternative Scenarios.

Variables	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Real GDP growth rate (%)	2.49	1.73	1.50	3.50	3.50	3.50	3.50	3.50	3.50	3.50
Nominal interest rate (%)	8.49	8.49	8.49	8.49	8.49	8.49	8.49	8.49	8.49	8.49
Minimum milk price in GO (R$/kg)	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89
Minimum milk price in all other states (R$/kg)	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
Corn price in US (US$/bushel)	4.27	4.76	4.54	4.68	4.59	4.59	4.54	4.51	4.46	4.56
Soybean price in US (US$/bushel)	14.63	14.77	15.41	15.32	15.29	15.07	14.87	14.62	14.37	14.13
Sugar cane acreage in Brazil (1,000 Ha)	5,287	5,428	5,572	5,721	5,873	6,029	6,189	6,354	6,523	6,697

Note: GO = Goiás

Table A-5. Milk Production, Dairy Cow and Milk Price: Baseline and Alternative Scenarios

	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Milk Production (1,000 metric tons)										
Baseline	34,225	35,047	35,844	36,655	37,468	38,288	39,114	39,949	40,795	41,649
High GDP	34,225	35,047	35,844	36,680	37,532	38,404	39,297	40,213	41,154	42,116
High interest rate	34,184	34,988	35,767	36,562	37,361	38,167	38,981	39,804	40,639	41,482
High min price	34,414	35,349	36,262	37,166	38,063	38,954	39,842	40,725	41,607	42,484
No-RFSUS	34,231	35,056	35,863	36,681	37,504	38,330	39,163	40,003	40,853	41,709
High sugar cane	34,215	35,022	35,798	36,586	37,376	38,170	38,971	39,779	40,599	41,425
Dairy Cow (1,000 heads)										
Baseline	23,883	24,253	24,603	24,932	25,250	25,560	25,862	26,158	26,450	26,737
High GDP	23,883	24,253	24,603	24,932	25,256	25,577	25,897	26,217	26,537	26,859
High interest rate	23,883	24,243	24,584	24,906	25,217	25,520	25,817	26,109	26,397	26,681
High min price	23,883	24,289	24,676	25,042	25,392	25,728	26,052	26,364	26,665	26,958
No-RFSUS	23,883	24,255	24,606	24,938	25,260	25,572	25,877	26,176	26,470	26,759
High sugar cane	23,873	24,227	24,556	24,861	25,153	25,435	25,709	25,975	26,237	26,493

Table A-5. Continued

	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Milk Price (R$/liter)										
Baseline	0.84	0.84	0.83	0.84	0.84	0.86	0.87	0.88	0.89	0.91
High GDP	0.84	0.84	0.83	0.85	0.88	0.90	0.93	0.97	1.00	1.03
High interest rate	0.85	0.84	0.83	0.84	0.85	0.87	0.88	0.89	0.91	0.92
High min price	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
No-RFS US	0.84	0.83	0.83	0.83	0.84	0.85	0.86	0.88	0.89	0.90
High sugar cane	0.84	0.84	0.83	0.84	0.85	0.87	0.88	0.90	0.91	0.93

Table A-6. Content of Dairy Products and Raw Milk in Terms of Milk Fat, Water, and Solids-Nonfat

Products	Milk fat	Water	Solids-Nonfat
Butter	81.30%	15.80%	2.90%
Cheese	26.00%	45.00%	29.00%
Skim milk powder	0.80%	3.50%	95.70%
Whole milk powder	27.00%	2.98%	70.02%
Fresh dairy products	3.10%	88.80%	8.10%
Raw milk	3.55%	87.80%	8.65%

Source: Torres, et al.(2000); LBR-Lacteos Brazil.