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Evaluation of the supply chain of key industrial sectors and its impact on the electricity demand for a regional distribution company

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Evaluation of the Supply Chain of Key Industrial Sectors and its Impact on the Electricity Demand for a Regional Distribution Company

by

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Dedication

To Karina for giving me all the strength I needed through her love regardless the distance and difficulties we passed to be together.

Also, to my mother, Marili, my father Carlos, and my brother Renato for their love, for giving me all the support I needed during my entire life and for teaching me the real important values to be esteemed.

Without you all, this work would not be possible.

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Table of Contents

List of Tables

List of Figures

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ABSTRACT

Considering the international scenario, in a recent past, the electrical industry was based on the concepts of monopolistic concessions and vertical utilities structures. In Brazil, until recently, the electricity companies were all governmental properties that served restricted monopolized areas. In a similar manner, in the United States, monopolies for certain concession areas were assigned to vertically integrated electric utilities. This monopolistic portfolio brought to the industry, in a generic sense, a lack in the interface between companies and consumers. This fact established a low capacity of obtaining consumer's information and consequently, a low capacity of developing precise demand forecasts.

Lately, the industry of electrical energy around the world has passed through immense structural changes, not only in developed countries, but also in developing countries. In this new environment, competition and private capital are fundamental agents. Now, demand forecasting represents a key factor to support decision-making for planning strategies of electricity utilities. In addition to immediate potential benefits to commercial decisions, a framework for electricity demand forecasting can help to take actions aiming to develop

more precise yearly budgets as well as to make accurate investments in the infrastructure expansion.

With the objective of improving the supply chain perception of the electricity industry, this work analyzes the electricity industry and develops a mathematical tool to accurately support the decision-making process of electricity utilities. CPFL Energy Co., a holding that controls companies and private enterprises in the generation area, electric power distribution, and trading in Brazil, was chosen as the case of study. CPFL Energy Co.'s supply chain was studied to find out the right explanatory variables and an electricity forecasting mathematical model was created through the stepwise regression procedure.

Chapter 1

Introduction

1.1. Current Supply Chain Management Stage of the Electricity Industry

Generally distinguished by vertical organizations, monopolistic concession areas and limited competition, electric utilities had very little customer relationship management (CRM) orientation until recently. Underneath a supply chain perception, this signifies a lack of information exchange and processes integration to fulfill customers' needs. With that, CRM tools such as electricity demand forecasts were usually based on qualitative methods primarily subjective and anchored in engineers' experiences.

Nowadays, considering the advancement of the deregulatory process and the private capital in the sector, competition is a new market attribute that forces electric utilities to improve marketing and customer relationships. Considering specially the industrial consumer segment, the free market concept is a reality that must be embraced by utilities to be adapted to the competition of the new era. Going on this way, accurate demand forecasts represent an elemental issue to support decision making for planning effective strategies. Accurate forecasts make possible properly dimensioning future expansion investments, and managing and controlling the facilities with precision. Underestimates signify not properly investing in growth while overestimates signify unnecessary large investments that can financially damage the company. Accurate forecasts permit also precise execution of management tasks such as establishing the appropriate supply of fuel for a thermoelectric plant. In addition, appropriately investing in its energetic infrastructure is a strategic struggling point for any country that wishes to promote economic growth. This aspect is very critical for developing countries, which face strong economic growth and need to proportionally allocate investment in new electricity generation.

All these changes are observed as a general worldwide tendency and can be seen in the Brazilian Electric Sector, which is the context in which this study is performed. According to Bajay (2005), "During the past decade, the Brazilian electric power sector went through similar institutional changes taking place in both developing and developed countries. The main goals for such changes were to inject competition into the generation and supply links of the sector's production chain and to reduce public debt via privatization of state-owned utilities that dominated the pre-reform sector."

In sum, nowadays, electric companies must have accurate forecasting systems now to be part of the modern phase of the sector and adapt companies to a new supply chain management perspective.

1.2. Forecasting Methods

Considering the modern business environment, inside any type of organization, the supply chain management decision-making procedure is dependent on demand forecasts. Several different factors are important to predict future demand. Chopra and Meindl (2004) state that some of these factors can be past demand, the state of the economy, the lead time of product, planned advertising or market efforts, planned price discounts and competitor's actions. Also according to Chopra and Meindl (2004), forecasting methods are separated according to four classifications:

- *Qualitative:* Mainly dependent on human judgment. It is important when not enough historical data is available and when professional market experience is fundamental. Applicable for a new industry, for example.
- *Time Series:* Standing on the hypothesis that past demand data is a good indicator of future demand, this method uses historical demand data to develop a forecast. This is the simplest method and is appropriate when the basic demand pattern stays considerably constant along the years.
- *Causal:* This method is based on the assumption that demand is strongly correlated with factors in the environment. The idea is to find the correlation of these factors with demand to make possible estimates of future values of demand. "For example, product pricing is strongly correlated with demand."
- *Simulation:* This forecasting method reproduces possible scenarios that determine future demand. "Using simulation, a firm can combine times series and causal methods to answer such questions as: What will the impact of a price promotion be?"

Being applied to the electric industry, this study is performed utilizing the causal forecasting method taking under account CPFL Energy Co.'s historical demand data and analyzing the company's environment aiming to find consistent explanatory variables to build a mathematical electricity demand forecasting model.

1.3. Objective

Recognizing the current deficiency in the electricity market related to customer relationship management, this work aims to evaluate the supply chain of key industrial sectors and its impact on the electricity demand for a regional distribution company. Especially dealing with the industrial electricity consumer segment, a connection among economic activity and electricity demand is evident. Particular social and environmental features also can reflect in the need for electricity. Therefore, this study identifies, evaluates and selects explanatory variables such as macroeconomic indexes, microeconomic indexes, key industrial sectors' production indexes, and other types of variables which impact a utility's electricity sales for the industrial consumer segment. After identifying the important explanatory variables, the final goal is to build a mathematical electricity demand forecasting model to serve as an important tool for the utility's management and planning.

CPFL Energy Co., a holding that controls companies and private enterprises in the generation area, electric power distribution, and trading in Brazil, was chosen as the case of study and its supply chain was evaluated to find out the right explanatory variables. The industrial electrical consumer segment was the one chosen to be studied, since it is the one inserted in the free electric market concept in Brazil.

Consequently, this work has the potential of impacting the electric industry and serving as a reference for future studies in the electricity demand forecasting area. Although the created model deals with explanatory variables which are directly related to a specific company and its environment, the study can be applied for any other electric utility aiming to develop its own specific electricity demand forecasting model.

1.4. Scope

Motivated to improve the supply chain perception of the electric industry, this work aims to analyze the current stage of the industry and develop an instrument so that decision agents can acquire an integrated vision of planning strategies and operations, including the dynamic interactions of markets to better insert the sector in the transformation process that has been advancing.

Chapter 1 presents an introduction of the matter discussing about the current supply chain management stage of the electricity industry and showing the objective and the scope of the work.

Chapter 2 shows a brief historical review about the electric industry legislation and the trend the industry is taking after the reforms. The reform processes of four countries are addressed: United States, United Kingdom, Norway and Brazil.

Chapter 3 discusses the formation of the industrial sector demand paying attention to the correlation of electricity demand and economic activity. Macroeconomic factors, such as *GDP, inflation, real income, and interest rates*, are briefly explained and their relationship to electricity demand discussed. Microeconomic factors and other demand formation factors such as exportation policies and governmental development policies are also addressed.

Chapter 4 addresses the current industrial electrical consumption forecasting methods. The current importance of the Brazilian industrial electrical consumer segment and the importance of accurate forecasting methods in the general electric industry are presented, too.

Chapter 5 presents the proposed methodology for industrial load forecasting at a distribution utility. It presents CPFL Energy Co. as the case of study and the importance of its industrial consumers segment. In addition, Chapter 5 presents the explanatory variables, the approach to analyze the data, the stepwise regression procedure that was used, the models obtained from the study, and the results.

Finally, Chapter 6 presents conclusions from the best model selected in the quantitative study and also presents conclusions and discussions from the qualitative study.

Chapter 2

The Organization of the Industry of Electrical Energy

Considering the international scenario, the industry of electrical energy has been passing through immense structural changes, not only in developed countries, but also in developing countries, propelled by the interaction of social, economical, institutional and technological growths. Several different reasons led governments to deregulate the power industry in their countries. According to Philipson and Willis (2006), some of the most important reasons are acquiring foreign investments through privatization and promoting competition in the vertical structure. These changes took the electric industry to a new environment where competition and the private capital are fundamental features to draw effective strategies.

Therefore, to adapt the electric industry to perform in this new competitive atmosphere many countries have implemented reforms aiming to restructure the sector, adjusting it to the private capital entrance.

The process of restructuring is complex and involves several changes and adaptations in the electricity sector as a whole. Miranda (2003) states that competition will lead to generation efficiencies and technological innovation causing probable decreases in price.

Consequently, the sector shows a tendency of moving from an industry based on public vertical institutions functioning in an environment with no competition to another based on private horizontal companies operating in an environment replete with competition. Today, countries see themselves in different stages of deregulation, as seen in Figure 2.1.

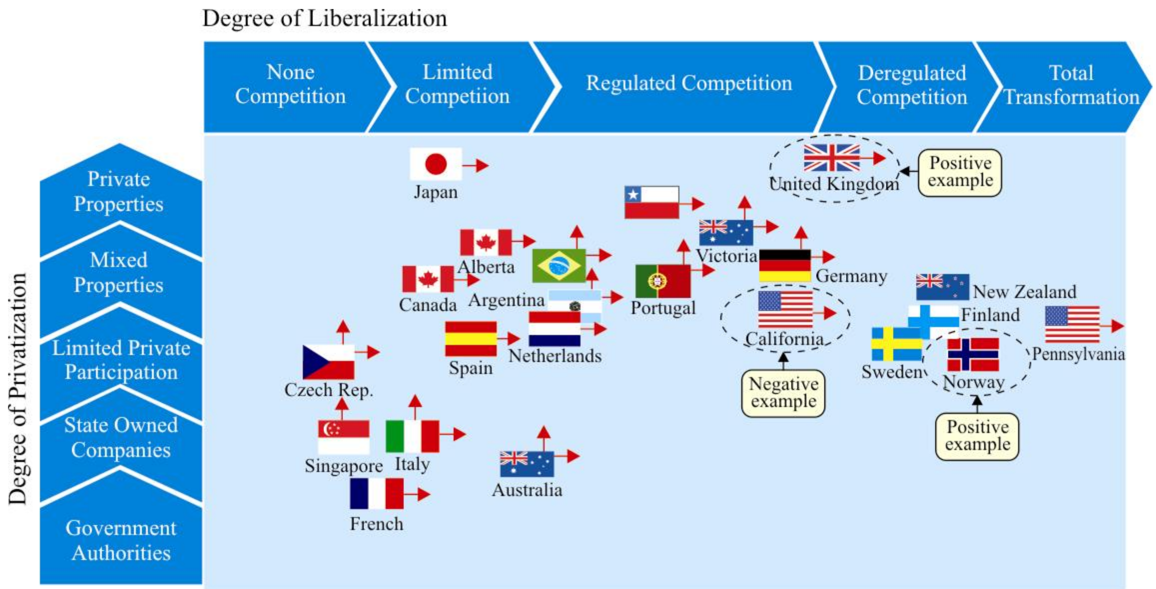

Figure 2.1 Degree of Privatization vs. Degree of Liberalization

Source: Comportamento dos Mercados da Europa e estados Unidos após a Liberalização do Setor de energia. *Value Partners* (2002)

In order to understand the general deficiency presented under a supply chain management perspective in the electric sector, a historical review of the legislation advancements of some countries are presented as examples. The reforms in United States, United Kingdom and Brazil (which is CPFL's country) are addressed, as well as the Norwegian case, as an exceptional one.

2.1. The Reform of the Electricity Industry in the United States

The electricity market in United States had very little legislation restrictions in its early years. Only several years after the invention of the light bulb in 1878, the regulation reform in the sector started to be a real concern. Therefore, the guiding principle for federal regulation of public utilities engaged in interstate trade of electrical energy was established by the Federal Power Act (FPA) of 1935, which gave ample authority to the Federal Power Commission (FPC) (Power Committee, 1948). The FPC had the right to issue licenses for new hydroelectric generation projects, collect operational and financial data including original investment costs and electric generation and sales data from utilities, and analyze electric rates and establish their depreciation plan. After the creation of FPA, utilities' requirement to charge fair rates was institutionalized and the companies were to make public all rate schedules for public and government examination, forcing them to establish rates according to the cost of service. Different consumers could not be charged differently without extensive justification anymore and permissible time frame for changes in rates was determined. In 1950, FPC´s powers were relocated to the Federal Energy Regulatory Commission (FERC), and later, to the United States Department of Energy (Power Committee, 1948).

In the same year, 1935, another important legislation against the multi-tiered holding company structure was approved, the Public Utility Holding Company Act (PUHCA) (Grossman and Cole, 2003). Before that, there were many commissions spread by many states with no significant authority specially when dealing with companies operating in more than one state. Also, almost half of the US electricity market was controlled by only 3 companies, thus centralizing the power in few hands. Consequently, because of the deficiency in regulatory supervision, holding corporations shielded themselves from regulations making an apparent separation of subsidiaries through multiple layers of holding companies to hide real costs and charge exorbitant tariffs. A common practice used by the holding companies was to charge excessive construction rates to their generation companies which transferred their expenses to the consumers by charging higher tariffs. This situation allowed a few holding companies to maintain significant power in the market, employing abusive practices because of deficient regulation.

In 1928, a report was issued by the Federal Trade Commission listing abusive practices and stating that this structure was a hazard to consumers and investors. Additionally, holding companies were able to hide debt in the course of their several layers, and utilities were able to carry enormously high debt ratios that ultimately caused their downfall after the stock market crash of 1929. With the Public Holding Company Act (PUHCA), the Security Exchange Commission (SEC) provided effective regulation of public utilities, and established heavy regulation to utilities operating in two or more states (Grossman and Cole, 2003).

It is important to mention that the PUHCA was a result of an effort of the federal government negotiating with holding companies. The Federal Power Commission would be responsible for rate regulation as established under the FPA of 1935, and the Security Exchange Commission (SEC) would be responsible for regulating the greater part of intercompany financial transactions as outlined in PUHCA. Holding companies would be responsible for providing reliable services at regulated levels in exchange for operating in an exclusive region (Grossman and Cole, 2003).

Some decades later, in 1978, endorsed to solve the “energy crisis” and the consequent supposed shortage of petroleum and natural gas, the Public Regulatory Policy Act (PURPA) was established as part of the National Energy Act. According to PURPA, utilities were required to buy electricity from non-utility generating facilities that produced energy from cogeneration or renewable energy sources (Grossman and Cole, 2003).

In order to open access to transmission networks and make it easier for non-utility generators to enter the wholesale market for electricity, the Energy Policy Act (EPACT) of 1992 was created (PacifiCorp, 2004). EPACT gave the states the right to provide open access to electricity lines for retail business. With that a new class of electricity producers called wholesale generators (EWGs) was created. This new class was exempted of PUHCA regulations, and this fact made it easier for utilities, affiliated or not, to compete to build new non-rate based electricity plants. In addition, EPACT offers transmission-dependent utilities the facility to shop for general electricity supplies, thus liberating them from their dependence on neighboring utilities. This act provided nationwide access to the electricity transmission system for wholesale business, giving an incentive to competition in the field regulated by FERC (PacifiCorp, 2004).

Also intending to foster competition in the national electricity market, FERC released the Order 888, in 1996, obligating utilities to create electronic systems to distribute information on an equality basis about transmission capacity (Grossman and Cole, 2003).

Three years later, in 1999, FERC Order 2000 was created asking for the voluntary creation of regional transmission organizations (RTOs) (Grossman and Cole, 2003). The idea was that independent organizations operating and controlling of regional transmission systems would be the best way to manage the transmission system. FERC had observed that managing the transmission grid by vertically integrated electric utilities was not adequate to the efficiency requested by a competitive market. The RTOs would be responsible for controlling all transmission units and for managing operational and reliability subjects. FERC Order 2000 would avoid possible opportunities for discriminatory practices, give more efficiency in transmission grid management consequently improving reliability, create lighter regulation, and improve market performance. Therefore, the main purpose was to build a more efficient transmission system across the country supported by RTOs with minimum common characteristics and functions. RTOs would also stimulate investment interests for construction of transmission assets and be responsible to facilitate transmission organizations trades.

More recently, in July 2002, FERC issued the NOPR RM01-12-000, a Notice of Proposed Rulemaking on Standard Market Design (SMD) with the intent of continuing the effort towards competitive electric markets adequacy. In 2003, FERC would issue the final regulation, but because of receiving several comments from NOPR, FERC issued a more general and flexible version to put into practice a wholesale market, known as the White Paper. The White Paper's general principles are based on regional independent grid operation, market monitoring, regional transmission planning process, regional resource adequacy, firm transmission rights and spot markets for real-time energy balancing. Also, according to the White Paper, state committees should still develop policy considering regional particularities. A final implementation rule has not been created yet (PacifiCorp, 2004).

As a consequence of delegating responsibilities to independent regional organizations, the development of a reorganized electric industry has advanced in a different pace in different regions. The map in Figure 2.2 shows the situation of state electric reorganization activities.

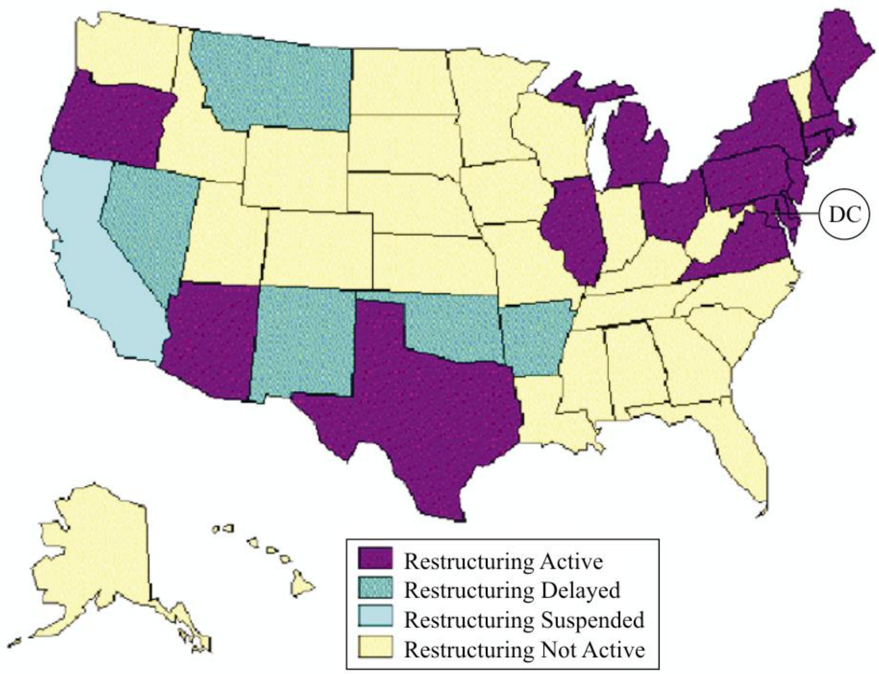

Figure 2.2 Retail Restructuring

Source: United States Department of Energy – Energy Information Administration website

2.1.1. The California Case

The restructuring act in the electric industry was initiated by the Assembly Bill 1890 (AB 1890) which came with the intent of lowering bills, and offering choice of generation suppliers among other objectives. However, no real attention was taken assume a continually adequate energy supply and demand. According to Harvey, Bentham and Heitz (2001), the plan intended to enable utilities to recuperate their "stranded costs" (costs of uneconomic plants) by fixing consumer retail rates at 1996 level for four years or until the cost is recovered, which ever comes first.

The crisis was a result of several problems. Some of these problems were related to demand, others to supply, and others to market manipulation. Related to supply, not properly investing in new resources, a reduction in hydroelectric generation and the increasing prices of natural gas were significant issues. In addition, the boom in the technology industry promoted a 20% demand increase from 1997 to 2000 and the fixed retail prices did not sign for consumers that the wholesale prices were drastically ascending. Finally, suppliers withholding energy at peak-hours to drive prices up intensified the crisis (Dubash et al, 2002).

According to Dubash et al (2002), in December 2000, the wholesale market price paid by utilities was $400.00 per megawatt-hour and the reselling price was still only $65.00. Utilities were losing approximately $50 million a day.

This experience is known as a case study on how not to approach an ideal transition towards a retail competition environment and retail choice was suspended in California in September of 2001.

2.2. The Reform in the United Kingdom

The reform in the United Kingdom is an important example because it has been used as a reference model for reforms of many other countries.

Before the privatization, the English electric sector was basically dominated by the generation of coal thermal plants and of nuclear plants. The reforms in the English electric sector were initiated during the eighties, to achieve some objectives, such as to improve the public finance and to introduce efficiency in the company's administration by privatization (Barbosa and Leal, 2005).

As part of the restructuring process, the government established a period of pre-privatization based on: vertical separation between generation, transmission, distribution and commercialization; liberalization of the generation market; horizontal and regional separation of distribution companies; and establishment of supply liberalization according to a gradual chronogram. Then, in 1990, the two main public generation companies responsible for 78% of the electric power generation, National Power and Powergen, were privatized, introducing a wholesale market and energy retail (Barbosa and Leal, 2005). However, the wholesale market (Pool) system permitted these two main companies to manipulate the prices, because distribution companies had limited alternatives for buying energy. At the end of the contracts in 1993, the proportion of energy separated by source in England was distributed according to the Figure 2.3.

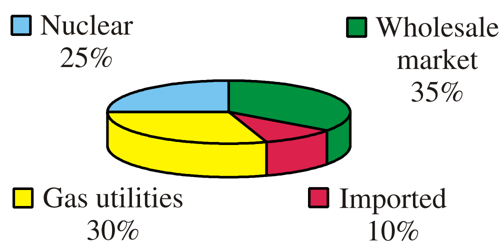

Figure 2.3 Proportion of Energy Separated by Source in England in 1993

Source: Barbosa and Leal, (2005)

As the remaining amount of energy for commercialization in the wholesale market was only 35%, the wholesale market was extinct in 1998 (Barbosa and Leal, 2005)

Considering that this market was not properly regulated yet, the majority of the investments in generation were accomplished in the two first years after the privatization. The prices of the sector were maintained in a good level, attracting new investments. In 2000, the generation market was better defined with ten companies which could supply at least 2 GW and none more than 10 GW (Thomas 2000). The new wholesale market of energy was being structured with a system based on auto-dispatch instead of centralized dispatch. The concentration of market power of generation companies decreased substantially, as can be seen in the Figure 2.4. The *Herfindahl-Hirschmanninde Index (HHI),* calculated through the marketshare squares sum of each agent, determines the level of this kind of concentration. All the markets which HHI exceeds 1.800 are considered highly concentrated markets (Value Partners 2002).

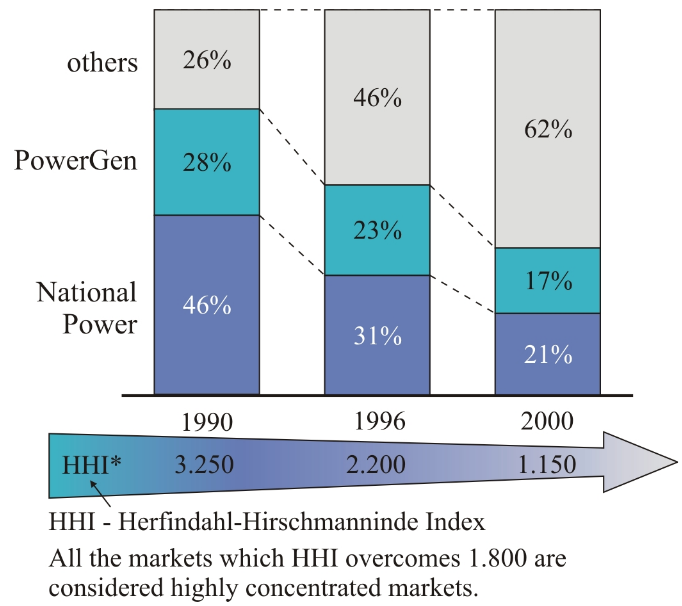

Figure 2.4 The Concentration of Market Power of Generation Companies

Source: Value Partners (2002)

From all the achievements obtained by the English Electrical Reform the most significant was a cost decrease, which reduced the prices paid by consumers 30%, and the increase of productivity acquired from technologically changing the fuel from coal to natural gas. Later, with an increasing unemployment index in the coal industry, the English government felt strong political pressures which resulted in the elaboration of contracts to stimulate the coal sector for some time, disturbing the regional distributors of electricity (RECs) that had to fulfill these contracts and to review their final prices.

2.3. The Reform in Norway

The Norwegian case is an important example to be studied because it constitutes a successful example of a truly and ample adoption of the free market in the electrical sector which is extended to all kinds of nets and consumers.

Similarly to the Brazilian electrical system, the Norwegian system is composed of 99% hydroelectric power generation. Norway is the sixth largest generator of hydroelectric power in the world producing 110 TWh in average. (ROSA et al, 1998). As a result, the system presents elevated fixed costs, reduced variable costs and elevated margin of spare capacity without restrictions. However, what is interesting is that instead of having a stable and small variation of energy prices, the Norwegian market presents a high volatility of prices. This phenomenon can be explained because of the random production of electricity derived from the stochastic variability in precipitation.

The great number of companies in the sector is another factor that enabled the system success. The generation segment is not concentrated as in England. In Norway, 34 large companies own 94% of the installed capacity. The transmission system is composed by high tension lines and average voltage regional nets owned by 54 concessionary companies from which 40 are also distributors. This is a determinant aspect to offer different prices and consequently, competition (Rosa et al, 1998).

The reform in this country started in 1990. A competition market in the generation sector was created, but the transmission and distribution chains were kept in the government's hands. Consumers from all types and classes (industrial, commercial and residential) were allowed to choose the electricity provider of their preference. With that, companies would have free access to all the nets, including the local, and the regional ones being subjected to competition from other companies. The retail market was structured with the intent of encouraging the free negotiation between final consumers and suppliers so as to encourage competition. The wholesale market was divided into two markets. The first is the organized market which consists in contracts between generators, distribution concessionary companies, great industrial consumers and, after 1995, small consumers. The second one is the market of bilateral contracts referring to a direct negotiation between generators and consumers (Rosa *et. al,* 1998). Interestingly, the formation of prices in the wholesale market is determined by a kind of auction, which prevents any imposition of producers according to the variation of the level of the reservoirs. To regulate all these interactions, a regulatory agency was created as well.

Alternative sources of energy have received incentives after the reform to put them in equal condition and they can compete with the hydroelectric generation in the same level.

Concluding, from the study of the restructuring model of the Norwegian electric sector, it is possible to observe its efficiency by generating competition among companies (even state-owned companies), and the spreading of the free market concept to all classes of consumer, including the residential.

2.4. The Brazilian Electric Sector

A study of the Brazilian electric sector is very important for this work to provide an understanding of the legislation that builds CPFL Energy Co.'s environment. This makes possible a better evaluation of the case of study context.

The Brazilian electric system has specific characteristics which make it unique. According to the Balanço Energético Nacional (2004), from the Ministry of Mines and Energy (MME), from the 175.2 GW installed in all South America, 82.8 GW are installed in Brazil. Considering the same year, 70.7 GW from the total capacity installed in the country (which represents 85%) come from hydroelectric sources, 10.1 GW have thermoelectric origin, and 2.0 GW comes from thermo-nuclear energy generation. The total electricity production in 2004 reached 300.6 TWh (Balanço Energetico Nacional, 2004). The total hydraulic potential of the country is estimated in 260 GW what can lead to the conclusion that only 25% is explored currently. Therefore, the preference for hydroelectricity can be easily explained because this energy source is cheap, abundant, and environmentally friendly water.

According to Bajay (2005), "Brazil is the largest economy in Latin America and the 9th largest in the world when measured in terms of Purchasing Power Parity exchange rates. It is the 10th-largest electrical power consumer in the world and the largest electricity consumer in Latin America. Brazil is, therefore, a very important player in the world energy theatre."

Another particular feature of the country impacting the form of the Brazilian system is the size of the country. Brazil is a country with continental proportions with twenty-six states plus the Federal District divided in five regions: South, Southeast, Centerwest, North, and Northeast. The continental dimension and the geographical and economic diversity of the country gave origin to different electric systems referred to regional markets with distinct characteristics of development. According to Pires (2001) only in 1999, the interlinking of the two transmission subsystems (South-Southeast-Centerwest and North-Northeast), was concluded enabling the exchange of 600 MW annually. Considering the national connection of the transmission grid, the size of the country, and the predominant hydraulic base of the electric generation, it was possible to develop a system based on coordinating the plants dispatch that generally are in different basins and "operate in cascade" planning to optimize the operation of the system to take advantage of the hydrology and seasonality diversities of the different basins along the country.

However, predicting future problems, and aiming to create investments in alternative sources of energy, Thermoelectric Priority Program (PPT), was created, through Decree (Decree 3.371, of 24/02/2000). The PPT was coordinated by the MME, and supports the installation of thermoelectric plants to provide emergency boosts in production.

2.4.1. The Development of the Brazilian Electric System

In the beginning, the privilege of generating and selling electricity was concentrated in only two foreign private companies, ANFORP and Light. The function of the government was restricted to concede permissions to companies' operation and there was no regulatory function. The tariffs, in this period, were transformed in an equivalent value in gold, called "gold-clause" ("cláusula-ouro"), so that these two companies got protected from the inflation and from the Brazilian coin devaluation. In this period, there were other private companies, but they had small size and did not interfere in the profit of the two monopolistic companies (Baer and McDonald, 1998).

The main aspect of this period was the total monopoly of two foreign companies that controlled all the chain segments, manipulating all the pertinent activities without allowing new competitors. According to Barbosa and Leal (2005), this period can be considered as an originator of perturbations in the national electric system considering a Supply Chain perspective.

In 1934 the installation of the National Water Code (Código Nacional das Águas) was an attempt of creating regulations to the private companies' activities in Brazil (Barbosa and Braga, 2003). This code instituted rules for the generation and supply of electricity and for water resources usage. Therefore, the government started to have the power of conceding concessions and enforcing rules. The usage of water resources started to be dependant of government authorization for concessions of 30 or 50 years, according to the amount to be invested. The tariffs started to be determined according to the operation costs and the historical value of the investments. The National Water Code meant the end of the "gold-clause", and theoretically, set conditions and rules to supply an increasing demand due to the beginning of the industrialization process in the country.

Foreseeing future problems to meet demand, in 1936, the Brazilian Association of Electric Power Carriers (ABCE), and in 1939, the National Board of Waters and Electric Power (CNAEE) were created (Baer and McDonald, 1998).

In 1945, the federal government made the first movement towards the future structure based in the state control of the energetic assets: The Sao Francisco Hydroelectric Company (Chesf) was created (Barbosa and Braga, 2003).

The regulatory process needed to be developed and institutional agents with defined obligations were consequently needed. In 1960, the Ministry of Mines and Energy (MME) was created. Some years later, in 1965, the National Department of Waters and Electrical Energy – DNAEE was formed with regulatory purposes, and the CNAEE was extinct in 1967. With that, the basic structure of the sector was consolidated, being the MME responsible for the energetic politics which would be executed by Eletrobras (state company created in 1962 to promote construction, operation studies and projects of generation plants, transmission and substations lines). The DNAEE would be the normative organ and controller (Barbosa and Braga, 2003).

During the 1960s, the growth in capacity and demand along the country requested to the national electric system to be progressively integrated to provide the most rational utilization of the energetic sources. Therefore, the Committee of Coordination of the Interlinked Operation (CCOI) was created, embracing generation and distribution companies of the Southeast region in 1969 (Barbosa and Leal, 2005). Two years later, the CCOI-south was created, addressing the southern region. At the end of 1973, CCOIs were substituted by the Groups of Coordination for Interlinked Operation - GCOIs, which had the purpose of coordinating, deciding or determining necessary providences to the rational use of the existing and future facilities in the interlinked systems of the regions Southeast and South (Barbosa and Leal, 2005).

During the seventies, with the petroleum crisis, Brazil was transformed, progressively, together with other peripheral countries, in an exporter of electrointensive products. Multinational companies were transferred as much as possible to countries, such as Brazil, rich in energy potential. In 1973, the structure based on state companies was finally consolidated. The Eletrobras system had Chesf, Furnas, Eletrosul, and Eletronorte (Bajay, 2005). A project based on big hydroelectric plants was created and the route for all the future investments for the next decades was settled.

In the 1980s, the system based on the state control started to show serious problems. The economy slowed down, and the electric companies were highly indebted mainly due to the investments in big constructions of the last decade. After 1979, the sector's situation got worse due to the increase of the international interest rates and by tariffs manipulation, used as an inflation control mechanism, in the period between 1982 and 1993. To complete the situation, the state monopoly in the sector made the market much too rigid, and inefficient (Bajay, 2005).

Consequently, aiming to promote competition to generate efficiency and solve the problems in the electrical sector and in other important sectors such as the telephone service market, the government decided to privatize its companies in 1990. Especially in the electrical industry, the companies' debts were very high, and the government declared to be incapable to assume it. Therefore, the sector would have to pass through a transformation process not only to privatize companies but also to adapt to a new reality mechanisms and the existing political planning mentality based on state control resulting in a myopic global vision (Bajay, 2005). Accordingly, the transformation process would need to address:

- Privatization: The Brazilian government promoted privatization to make the private initiative responsible for new investments and promote competition in the electricity market. Moreover, selling the companies would provide money to the state.

- Vertical Separation: Separation of generation, transmission and distribution activities to guarantee free access for all producers to transmission and distribution nets. A unique company would only be allowed to perform more than one of these activities, if a rigid account separation existed.
- Free access to transmission and distribution nets all along the country was instituted to promote true competition among companies.
- Biddings for the construction of new plants.
- Reorganization of regulation and strategic planning agencies searching for creating a global vision with combining operations and integrating activities.

After a pre-privatization period from 1990 to 1995, the Brazilian government decided to act more aggressively in the electric sector, speeding the privatization process and developing the regulations. In December 1996, The DNAEE was extinct and the National Agency of Electric Power was created (ANEEL), entailed to the MME, with the attributions of regulating and verifying the generation, the transmission, the distribution and the commercialization of electricity, to attend agents' and consumers' complaints, to mediate the interests and conflicts among agents of the electric sector and between agents and the consumers, to allow and to authorize energy facilities and services, to guarantee just value of tariffs, to analyze the service quality, to stipulate investments, to stimulate the competition among generators and to assure services (Barbosa and Leal, 2005). In 1998, assuming the GCOI's functions, the Independent System Operator (ONS) was also created to operate the Interlinked National System (SIN) and administrate the electric transmission net (Barbosa and Leal, 2005).

Another important fact was the creation of the Energy Relocation Mechanism (MRE) responsible for relocating energy to equalize the risk between generators considering hydrologic diversity. The central idea is based on the assured energy capacity determined by the ONS for all the generators (excluding the thermoelectric). The amount is only allocated if the total production is greater than the total insured energy. Penalties are imposed to generation plants for very elevated unavailability average in an observation period (ANEEL Website, 2007).

The year of 2001 marked an important episode in the history of the Brazilian Electric System. A deficit in the generation system which did not follow the increase of power demand proportioned a national rationing program. In addition to the insufficient amount of investments in the national generation park, the low levels of the reservoirs in 2001 caused a problem that impacted not only the electricity demand, but also related activities, (Bajay, 2005). The rationing impacted electric energy consumption, affecting the entire electric chain, and consequently, the economy, the national politics and even the life of the population. ANEEL together with the National Secretary of Energy created a project imposing fines for consumers which surpasses certain levels of consumption to control the demand. The electricity consumption suffered a reduction of around 24% in Brazil (Bardelin, 2004). The Figure 2.5 shows the Brazilian monthly consumption (TWh) from 1998 to 2001 presenting the real consumption after the rationing and forecasted consumption not considering the advent of the rationing.

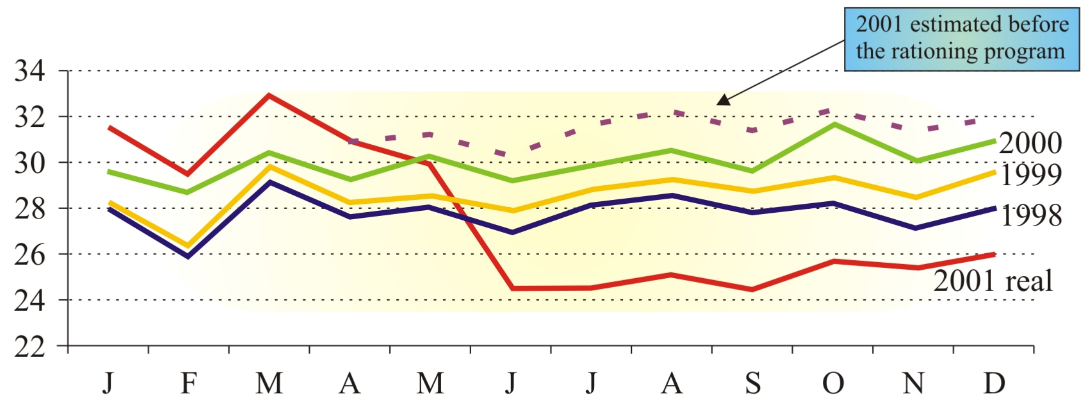

Figure 2.5 Monthly Electrical Consumption in Brazil (TWh)

Source: GONZÁLEZ, O. (2002)

Another interesting impact observed was observed in the Brazilian GDP, showing that the rationing impacted directly the economy, as it can be seen in Figure 2.6.

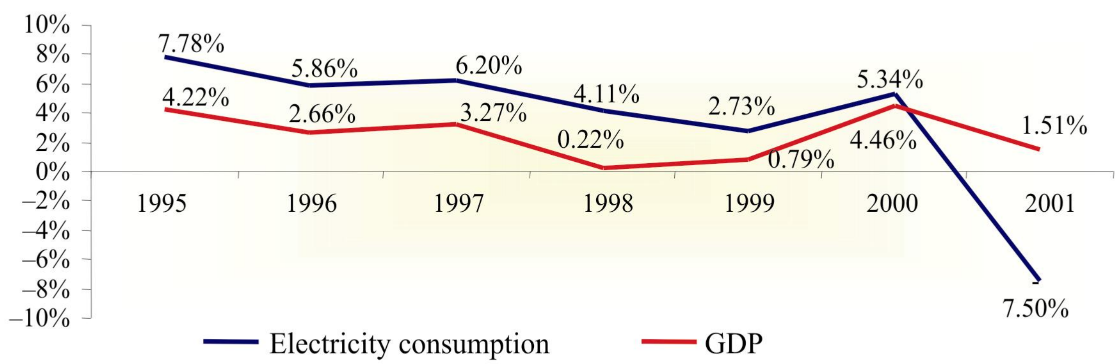

Figure 2.6 Electricity Consumption x GDP in Brazil

Source: Eletrobrás and IBGE in Paulo and Leal

As a response for this crisis, in 2003, the federal government created the "Proposal for the Electric Sector Institutional Model", with the main objective of guaranteeing security of electrical energy supply (Bajay, 2005). The Electrical Energy Commercialization Chamber (CCEE) was created to manage electricity commercialization contracts; organize auctions for the regulated environment; and mediate, promote, and supervise contracts for free consumers (Abreu, 1999).

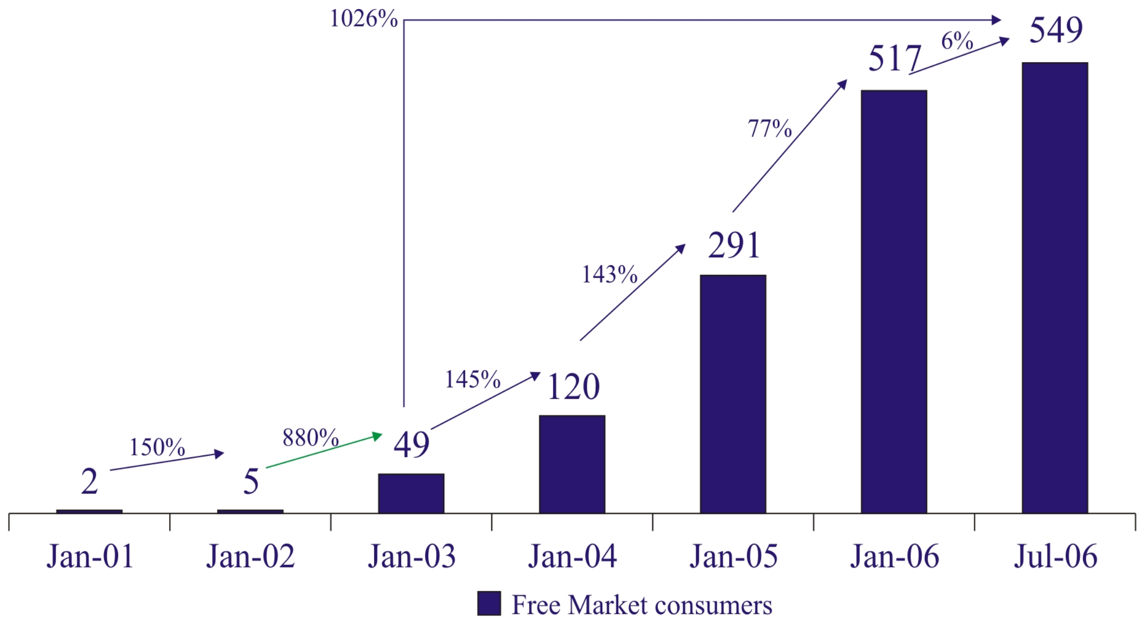

Figure 2.7 Number of Free Market Consumers Growth

Source: CCEE Jul/06

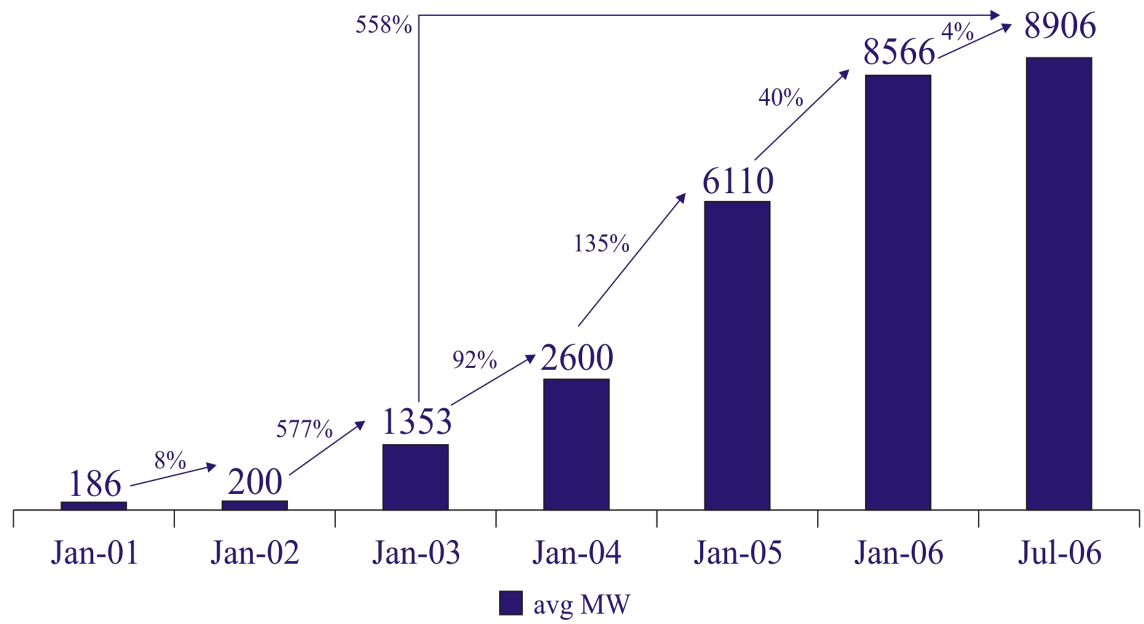

Figure 2.8 Free Electricity Market Consumption Evolution

Source: CCEE Jul/06

As a consequence, the new structure brought some changes. One of these changes is the considerable increase in the number of free electrointensive consumers (big industrial consumers with the right of choosing their electric supplier establishing contracts). As shown in Figure 2.7, the quantity of free consumers jumped from 49 in January 2003 to 549 in July 2006. Therefore, recognizing this change, the Brazilian government took actions to consolidate this market. First, the Free Environment Contract (ACL) was created under the Decree 5,163 for the establishment of an environment for regulating electric power trading; and bilateral freely negotiated contracts attainment. From this point, the national government has extended the Free Market. In the new model, the government restricts its responsibility to assist the small consumer market, in other words, the government operates in the regulated market. The large consumers (electrointensive consumers) started to be encouraged to migrate to the free market and sign contracts with freely negotiated terms with generators. With that, the free market expanded in size and importance. According to the Balanço Energético Nacional 2004 which is an annual national energy report, 44.3% of all the electrical energy generated is used by the electro-intensive companies in 2003.

According to Longo and Bermann (2002), the privatization process in Brazil was initiated without an ideal reformulation of the set of rules. This fact made changes happen even slower. However, now, the Brazilian utilities live in a new environment generated with the advance of privatization and consequent competition. In this new environment, electricity companies started to have a different strategic approach moving to a posture where consumers' satisfaction is a priority. In the past, the electrical energy industry was based on the concepts of monopolistic concessions and vertical utilities structures. This monopolistic portfolio brought to the industry, a lack in the interface between companies and consumers that still have sequels. Therefore, because of the past history of monopolistic portfolio, electrical utilities still have a low capacity of obtaining consumer's information and consequently, a low capacity of developing other important tools such as precise demand forecasts which are a vital today. In this way, improving marketing and customer relationship is a current goal to improve the utilities' foundations on strategic planning. This study has the final goal of improving this relationship.

Chapter 3

The Formation of the Industrial Sector Demand

The behavior of electricity demand trends is clearly connected to economic growth. Higher investment in the market as a whole means higher production, which, in the end, means higher demand for electricity. However, several components impact the economy which constitutes a complex model with many variables. Macroeconomic factors, regional development, exportation policies, national policy for industrial development, governmental incentives are some of these impacting components.

Macroeconomics is understood as the study of aggregated economical components, analyzing their influences and relationships among each other and their impacts in the entire economy (Hunt, 1982). Therefore, macroeconomics differs itself from microeconomics because it considers the importance of big aggregates and makes possible whole picture examination of the economy of states, regions, countries and continents. As a result, these aggregates represent important indexes for measuring economical activities and, consequently, can be linked to energy consumption.

The first important index related to the economic activity of any country, is the *national product*. The *national product* signifies the monetary value of all final goods produced in a country's market observed in a specific interval of time (Hunt, 1982). Closely related to this concept, the *national income* is obtained by the total of payments for all the production factors to obtain the *national product.* There are also several other indexes that are derivations of the same basic concept. Probably the most used and significant way of measure, the *gross domestic product (GDP)* is formed by the income which comes from the production accomplished inside the territory of a country. Therefore, the *GDP growth index* establishes the increase of goods and service generated by an economy in a determined period of time and can be associated to an increase of production and consequently can be related to energy consumption (Hunt, 1982).

Inflation is another important impacting agent of the economy. Inflation can be defined as the generalized and continuous rise of the level of all prices in a country. As a consequence, inflation represents a depreciation of the real value of the national currency. There are two main classic categories of inflation according to the traditional classic economical literature: *cost inflation* and *demand inflation*. *Cost inflation* takes place due to the elevation of cost prices of important materials or services. The level of demand stays almost stable. *Demand inflation* is considered the most typical type. This type of inflation comes from excess of aggregated demand and insufficient production for goods and services (Hunt, 1982).

Among several other problems, inflation causes the reduction of buying power of classes which are dependant on fixed income (salary). Also, high levels of inflation make the national product more expensive than the imported one. This stimulates the importations, holds the internal production designated to exportation provoking a subsequent decrease in the balance of payments. Additionally, the depreciation of the real value of the currency provides uncertainties for investing in production because of the extreme uncertainty of obtaining real profit. On the other hand, small or even negative growth of inflation is not good a signal. It shows, generally, that the economy is not growing sufficiently, or even slowing down (Lacerda, 2005).

As it can be seen in Table 3.1, inflation was always a significant problem to the Brazilian economy, specially, after the seventies. In the 1980s, Brazil suffered a phenomenon called hyper-inflation. In 1990, the annual inflation index reached its highest value, 2,596% what signifies 84% per month (Lacerda, 2005).

Directly connected to the notion of *inflation*, *currency rate* is another important parameter for any national economy. Representing the largest economy of the world during an extent period before the creation of the European Community Market, the *U.S. dollar* still works as a reference for other currencies' values and as the official currency for international business. Especially for developing countries, the *dollar/local currency rate* reflects directly in the local economy performance. A balanced ratio signifies a wealthy economy. If the ratio is too high, the economy suffers several problems such as a growing up inflation caused by the high prices of imported products. On the other hand, if the ratio is too low, the exports generate less money for local producers, indicating less money circulating in the economy, less investment and less need for energy. In both cases the balance of payments is negatively affected.

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Table 3.1 Brazil: Annual Inflation Indexes (Dec/Dec) – (General Index of Prices)

Years	Inflation Indexes IGPM	Years	Inflation Indexes IGPM	Years	Inflation Indexes IGPM	Years	Inflation Indexes IGPM
1948	8.3	1961	47.7	1974	34.6	1987	415.8
1949	12.2	1962	51.3	1975	29.4	1988	1037.6
1950	12.4	1963	81.3	1976	46.2	1989	1782.9
1951	11.9	1964	91.9	1977	38.8	1990	2596
1952	12.9	1965	34.5	1978	40.8	1991	416
1953	20.8	1966	38.8	1979	77.2	1992	969
1954	25.6	1967	24.3	1980	110.2	1993	1996
1955	12.4	1968	25.4	1981	95.2	1994	2240
1956	24.4	1969	20.2	1982	99.7	1995	77.55
1957	7	1970	19.3	1983	211	1996	17.41
1958	24.3	1971	19.5	1984	223.8	1997	8.25
1959	39.5	1972	15.8	1985	235.1	1998	4.71
1960	30.5	1973	15.5	1986	65	1999	4.33
						2000	8.57
						2001	10.06

Source: Conjuntura Econômica Magazine (several numbers), Getulio Vargas

The role of government in the agents of economy and directly in energy pricing and demand management is evident. Monetary, fiscal, and regulatory policies are imposed to promote positive impacts *in inflation, real income,* the *balance of payments*, and *foreign indebtedness*. Other government interventions have national security concerns also. Therefore, there are direct government's interventions on price as price control and possession of supply sources, and indirect influences on the market using import duties, taxes, subsidies, energy-using equipment taxes, and government-guided investments in energy resources. All these governmental actions promote impacts in the economy in the form of cost and final prices (Munasinghe and Schramm, 1983). *Interest rates* in Brazil are a good example of economy control policy. The *Selic rate* is the financing rate in the interbanking market for one day operations (*overnight*) which own ballast in federal public titles negotiated in the Special System of Sale and Custody. In other words, this rate is used for very short-term operations among banks, offering public titles as ballast, aiming to reduce the risk, and, consequently, the transaction remuneration. This rate is not fixed and varies practically every day, but inside a very small interval, since in the great majority of times it tends to approach the goal of Selic which is monthly determined by Copom (monetary politics decision organ created by the Central Bank and responsible for establishing the goal for the Selic rate). With the intention of holding external investments inside the country, the Brazilian *annual basic interest rates* (*Selic*) reached more than 19% in 2005, from far, the highest in the world (Hunt, 1982).Although this extremely elevated value in actual fact hold investments inside the country, it also breaks down the growth of the whole market, making new investments in the economy a lot smaller than it needs.

Taking a supply chain perspective, it is interesting to observe that government ownership is less common in petroleum and gas production. "It is less so in petroleum and natural gas production, refining, and distribution, where, however, joint ownership is frequent, or where government-owned systems operate side by side with the privately-owned ones" (Munasinghe and Schramm, 1983).

Other very important governmental proceedings which can impact directly the energy consumption are development policies that promote investment for industry production, infrastructure and economy enlargement. A very good example is the governmental plan implemented by the Brazilian president Juscelino Kubitschek (JK), called "*plano de metas*", the "*Goals Plan*". Before 1956, Brazil had 60% of the population living in the rural areas. This meant that 30 million people depended on the agrarian economy (Silva, 2006). Thus, it was time to modernize the country and to invest in development, generating growth and jobs. Continuing what was started by the president Getúlio Vargas some years before, the plan's purpose was to install the imports substitution process. Studies of a Brazil-USA Mixed Commission, as well as of the National Bank of Economic Development (BNDE) indicated the need for eliminating the "strangling points" of the Brazilian economy (Silva, 2006). Soon after taking over the government in 1956, President Kubitschek presented to the population his ambitious *Goals Plan*. The *Goals Plan* mentioned five basic sectors of the economy where public and private investments should be channeled. The sectors which received more resources were energy, base transportation and industries, in a total of 93% of the allocated resources (Silva, 2006). The base industries' growth, fundamental for the industrialization process, was of practically 100% along the years between 1956 and 1961 (Silva, 2006). Additionally, JK promoted the construction of a new federal capital, Brasilia, using the argument that Brazil needed a geographically centered capital. The new circumstances that were presented in the country, however, generated a dilemma. At the same time in which the country growth and development were evident, the country started to face other problems caused by this policy. *Inflation* and *external debt* were part of this legacy. On the other hand, the *Goals Plan* changed the national profile, developing industry, energy infrastructure and moving the country from its agriculture dependence to an industrialized position, which unquestionably promoted energy consumption growth.

Other times, the absence of planning can be another fact that impacts the energy market in a country. Underestimating future investments in energy infrastructure will definitely result in a strangling point for economy's growth in the future. As mentioned before, the absence of observing future trends and planning investments in electrical infrastructure generated a significant energy crisis in Brazil in 2001. These inappropriate investments in electrical infrastructure resulted in a deficient electricity supply which did not meet the demand. To solve this problem, the Brazilian government developed a national rationing program. The rationing impacted electric energy consumption, affecting the entire electric chain, and consequently, the economy, the national politics and even the life of the population (Bajay, 2005). Consumers were obligated to consume less and, as a consequence, society created new habits that dropped down considerably consumption. This fact resulted in an electric market shrinkage that affected all the chain impacting the Brazilian GDP (shown again in Figure 2.2) and reducing the consumption in all the main electricity consumer sectors, as it is shown in Figure 3.1.

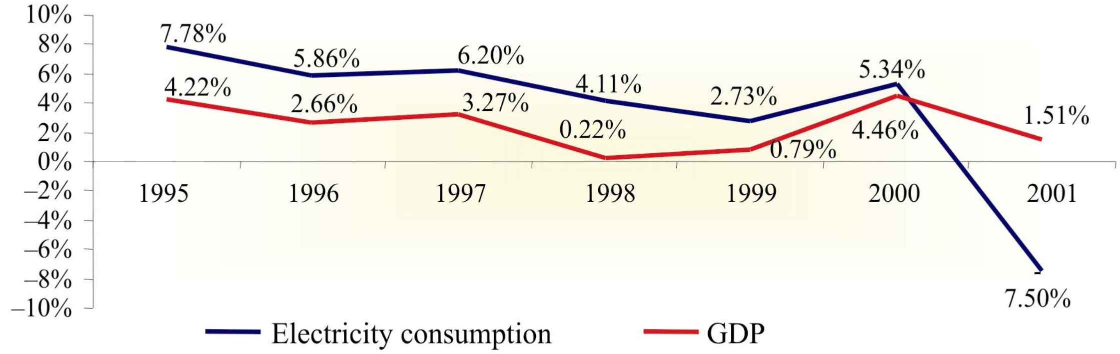


Figure 3.1 Electricity Consumption vs. GDP in Brazil

Source: Eletrobrás and IBGE in Paulo and Leal

International relations and the country's image are other important factors to its own economic health. The expression *Emerging Markets Bond Index Plus* (EMBI+) was added to everyday language of the economic news, mostly in countries that live in a climate of instability, such as Brazil and Argentina. The EMBI+ is an indicator that tries to determine the degree of economic instability of each country. Thus, it became decisive for immediate future of the emerging countries. The EMBI+ is calculated by risk investment classification agencies and banks. The American bank J. P. Morgan, which owns branches in several Latin-American countries, was the first to make this classification. J. P. Morgan analyzes the debt instruments revenue of a certain country, mostly the value (interest rate) with which the country intends to remunerate the applicators in bonus of the public debt. Among others, it evaluates aspects such as the level of the fiscal deficit, political turbulences, the economy growth and the relation between levies and debt of a country (Guimaraes and Fava, 2003).

All these concepts are parameters of how strong economic activities are, and consequently, can serve as parameters to analyze the national energy demand. However, there are some facts that influence the energy demand, but are not easy to predict.

Unpredictable happenings are as well part of the complex model that builds the economy ways. International crises are often hard to predict, but have strong impact on the world economy, and on the demand for energy. The gigantic consequence of the oil crisis in the 1970s is a well known example of a macroeconomic happening impacting the whole world economy. The seizure of the petroleum supply to the United States and to Europe established by the Organization of the Petroleum Exporting Countries (OPEC) provoked a world crisis. This measure was taken in reprisal to the support from the USA and of Western Europe to the occupation of Palestinian territories by Israel, during the War of Yom Kippur (Abreu, 2002) petroleum barrel price jumped from U$ 2.9 to U$ 11.65, increasing 301% in 1973. Countries which had their generation system based on thermoelectric production, such as United States, felt direct consequences on energy prices and consequently, in electricity demand. Industry was affected, transportation costs increased tremendously and the entire economy slowed down. The world economy was affected and even countries which based their electrical generation in hydroelectric producers, such as Brazil, were strongly hit. According to Abreu (2002), the trajectory of the economic stagnation and the extreme inflation observed after the 1980s has its origin in the imprudence regarding the form of facing the petroleum crisis of 1973. Similar consequences were observed in similar combustible crises such as the one provoked by the Kuwait War.

Other international crises, different in nature, also can affect energy demand. For developing countries, international crises originating in other developing countries represent a fear of investments in this category of countries, and consequently, represent a threat for economy stabilization. Consequences of crises in Mexico, Russia, and Asian Tigers were profoundly perceived in developing countries such as Brazil, Argentina, Chile or India. The crises promoted holds in the internal economy reflected in a decrease of energy demand growth.

As these occurrences can hardly be predicted, they can not be taken as variables for studies, such as forecasting of prices or demand for any market.

Chapter 4

Electrical Industrial Consumption Forecasting Methods

Today, demand forecasting represents a key factor to support decision making for planning strategies of companies from any sector to meet customer needs in an efficient way. Demand forecasting complexity has been constantly growing, as in modern days accuracy is fundamental.

In the past, the need for precision was a secondary concern, and as general rule, overestimates were approximated by demand increase in the electricity demand forecasting field. Therefore, excess capacity would be absorbed in a close future, not constituting a significant problem. In contrast, underestimates could be corrected with relatively small investment, setting up turbine generators in a short period of time (TERI Institute Web Page, 2006). Also, economy of scale, less concerns about environmental issues, and the simplicity of the regulations made demand forecast significantly simpler at that time. So, straight-line extrapolations of historical energy consumption trends were enough to provide acceptable projections (TERI Institute Web Page, 2006).

Today, the current scenario is much more complex and that makes the forecasting methods more complex as well. The essence of forecasting has assumed other purposes overtime. Predicting the peak demand and total energy annually used is not sufficient any more. This complexity added to the current extreme need for higher precision really makes demand forecasting a “difficult art” now (TERI Institute Web Page, 2006). Underestimates can result in undercapacity which leads to bad services and even to blackouts in an extreme case. Overestimates can result in big investments that are not needed and can affect the financial health of the utilility. In this way, taking into consideration the continuing reform process of the electricity sector which drives to a growing importance of private investments in this industry, demand forecasts projecting realistic scenarios are essential.

For that reason, the energy industry has been developing a variety of business models to face the new challenges of competitive markets. Short-term demand forecasts determine parameters for functional level strategy decisions such as planning operation and maintenance; and developing more precise yearly budgets. Further, short-term forecasts have the important function of developing a responsible tariff structure proportional to costs of generation and transmission, and according to consumer category-wise behavior.

In addition to immediate potential benefits to commercial decisions, long-term demand forecasting deals with the corporate level strategy. Demand forecasting can help to take actions aiming to orient future investments in the infrastructure expansion searching for optimal results. Hydro and thermal plants' conception period (planning, designing and constructing) varies from 7 to 12 years, which forces the utilities to develop precise demand forecasts for even more extended periods. Utilities must have enough time to plan and build considerably ahead of future consumer needs.

Additionally, demand forecasts are fundamental not only for electrical facilities, but also for governments' plans for energy infrastructure which needs to be always proportional to the demand in the country (Azevedo, 2002). The theory of demand-side management, a concept that plans the energy sector from both a government and business perspective responsive to the energy policies and market needs, would not exist without demand forecasting tools. Demand-side management embraces the ability to get a demand answer to a deficiency in the supply capacity (Gellings 1992). This point is even clearer in developing nations, where the industrial growth is in a drastic stage, and consequently the demand is growing in a significant manner. Governments of developing countries must have accurate forecasts about future demand to adequately make and stimulate investment in new capacity. With the exception of countries like Lithuania, which has overcapacity due to the infrastructure inherited from its past created to integrate the energy sector of the Soviet Union (Miskinis, 2003), developing countries have the need of rationally investing in their infrastructure. In that manner, the Brazilian electrical sector, for example, has been elaborating energy demand forecasting methods to support the plan of expansion of generation and transmission while optimizing operation (Azevedo, 2002). High precision demand forecast is such an important issue that ANEEL, the Brazilian Electric Energy Agency established a fee for five year forecasts which presents an error of 5% or larger (Azevedo, 2002). Additionally, forecasts are the drivers for planning investments, and finding ways for meeting demand considering concepts such as energy conservation and the impact of new technologies in the field as well.

4.1. The Impacts of New Technology

Today, new ideas and investments generate new technologies faster than ever before. Consequently, the impact of new technologies needs to be considered in the forecasting practice to achieve even more accurate results. New technologies and machinery create a higher need for consuming electrical energy (which increases energy demand), or/and establishes more efficient processes reflecting in an improved usage of work and power;

and in a reduction of losses (which decreases energy demand) (TERI Institute Web Page, 2006). Energy conservation is a current and important issue that has significant impacts on electricity demand. Concepts like green houses are a reality and the protection of the environment, which includes the existence of fossil fuels, is elemental. As historical data is considerably difficult for this matter, a different technical procedure is required based on objective models or on subjective models. Subjective models are generally mental procedures that can have quantitative or qualitative inputs and are based on management experience.

On the other hand, having a considerable quantity of historical data based on the impact of similar previous technologies in the same environment, objective models can be applied. Algorithms such as extrapolations, model-based methods, causal methods and econometric approaches can be applied (Indiana Electricity Projections, 2002).

As an example to illustrate the importance of this theme, the State Utility Forecasting Group (SUFG), from the state of Indiana, United States, has applied a meticulous model of the iron and steel industry, scenario-based models of the primary metals industry, and an industrial motor drive model to estimate the effect of new technologies in various forecasts (Indiana Electricity Projections, 2002).

4.2. Current Methods

In the past, straight-line extrapolations of historical energy consumption trends were sufficient to develop forecasts considering the relative simplicity of the scenario. However, now, an ample range of methods were developed to better adapt the demand forecasting to the current complexity and needs for accuracy of the electricity market. This part of the text will address the most commonly used methods.

4.2.1. End-Use Method

The End-Use Method centers on analyzing the different uses and applications of electricity in all the different categories of consumers. Therefore, refrigeration, air conditioning, lighting and other usages are analyzed in each category (industrial, residential, commercial, and agriculture). The equation below defines this methodology according to Gellings (1992).

$$E = S \times N \times P \times H$$

E = energy consumption of an appliance in kWh

S = penetration number in terms of such appliances per customer

N = number of customers

P = power required by the appliance in kW

H = hours of appliance use

This method requires highly detailed information about the usages. It is recommended with the presence of recent insertion of new technology resulting in a deficiency of time-series data on trends in consumption. The problem of this methodology is that it does not consider behavioral and cultural aspects of consumers and demographic and socio-economic factors. This method has been used, for example, by the Indian Central Electric Authority in the Electric Power Survey (EPS) to forecast the consumption of high tech industries (TERI Institute Web Page, 2006). Although this method is being related to demand forecasting for electricity, this method can also have a broader application to address many other issues that fulfill many of the end users' needs in many projects. A good example is that it is a fundamental factor for green design and development recognizing how to extract the greatest benefits minimizing financial and environmental costs (Gellings, 1992).

4.2.2. Trend Method

The Trend Method's biggest advantage is its simplicity. It determines the variables just as a function of time, and as a result, time is the only determinant factor putting aside economic, political, and any other influent factor (TERI Institute Web Page, 2006). Consequently, the biggest criticism is that this technique disregards interactions of the variable to be found and other factors, especially, economic ones. Prices, GDPs, population growth, and other factors are neglected. As a result, it is a non-causal model. This is why this approach is most appropriate for short-term purposes, especially as a cross check procedure or as a way to find preliminary estimates. According to TERI Institute (2006), this method was also used in India (EPS) to predict the electrical consumption of consumers with the exception of high tech industries.

4.2.3. Econometric Method

The Econometric method is a system of equations made of a combination of economic theory and statistical techniques creating causal relationships between electricity demand and economic factors (Gellings, 1992). The variables can be income per capita, price of power, population, price of fuels, and other significant factors which impact the dependent variable which is electricity demand. Therefore, in a general way, this concept could be summarized by the following equation (Gellings, 1992):

ED = f (GDP,Y, P, Pf, POP, T)

Where

ED = Electricity Demand

GDP = Growth Domestic Product

Y = Income

P = Price

Pf = Price of Fuels

POP = Population

T = Technology

An appropriate and functional equation must be worked out to meet the needs of particular markets and segments. Each segment or market derives demand for electricity taking into consideration different factors that have different importance. As a general example, industrial electricity demand forecasting can give more significance to information such as the income of power intensive industries, information about the gross fixed capital, investments, government policies, and technology renewing. On the other hand, residential electricity forecasts can give more significance to other factors related to income per capita, population, and price of tariffs.

To be able to establish short-term and long-term relationships with the variables, the approach requires a reliable set of information over a considerable period of time. Another concern relies on the difficulty to absorb the impact of policy measures and economic shocks on the variables to be explained, which needs to be embodied in the model, possibly in a structural change factor shape (Gellings, 1992).

There are some variances to this approach, and one of them is the Fuel Share Model, which can be used in most countries in the world since they mainly obtain energy from fossil fuels. This specific method first estimates the total energy consumption of a sector. Then, these estimates are used to determine ratios of fuels consumed by each sector to determine total energy consumption. A criticism of this method is its deficiency to recognize the interdependence of quantity and prices as it assumes that energy consumption does not impact fuels prices (TERI Institute Web Page, 2006).

A pertinent illustration of the application of the Econometric Method is INDEED, used to project the electricity consumption of 16 major industry groupings in the state of Indiana, United States. Aiming to project individual industrial electricity sales for the 16 industries, this model was developed by the Electric Power Research Institute (EPRI), and has been used by the State Utility Forecasting Group (SUFG) since 1992. The INDEED is a econometric KLEM model calibrated using data on cost shares obtained from the U.S. Department of Commerce Annual Survey of Manufacturers at the statewide level (Indiana Electricity Projections, 2002). Econometric KLEM model starts from the statement that companies perform always intending to minimize costs to create acceptable level of output. Consequently, it forecasts the consumption of the inputs capital, labor, electricity, natural gas, distillated and residual oil, coal and minerals individually or each of the 16 industry groups which come from the assumption that output must be minimized (Indiana Electricity Projections, 2002).

4.2.4. Aggregation

Aggregation is a non-linear process, and must consider the allocation of the explanatory variables. Group probability of choice is normally different to the probability of choice a single object would have. Therefore, forecasts of individual choice performance must be joined into groups of interest of the study. In this fashion, as the name says, this procedure aggregates the load shape to determine a trend that will define the forecast. Demand side management aspects are applied on the method which can be very useful for long-term forecasts. The Public Service Electric and Gas Company, from United States, designed a computer program named Electric Load Curve Synthesis (ELCS), which has the capacity of developing forecasts for 30 years in the future. This model has the capability to analyze the influence of several end-use employments considering the inclusion of demand side management evaluation in the process (TERI Institute Web Page, 2006).

4.2.5. Disaggregation

This process decomposes a load shape, defined by regression methods or an econometric approach, into elements, modifying the original shape according to demand side management purposes. This procedure allows projecting the load shape for the future. The disaggregation method is recommended to make prior estimates. However, this method is considered poor in further information which restricts its use (TERI Institute Web Page, 2006).

4.2.6. Time Series Method

The objective of any forecasting approach is to foretell the systematic factor and estimate the random factor (Chopra and Peter, 2004). Time Series approach is fundamentally based on the broad idea that future performance is related to past performances considering adjustments to set how past facts deviates from the ones in the future. So, analyzing the demand data it is possible to extract a level, a trend, and a seasonal factor. These factors are called systematic components (Chopra and Peter, 2004).

Therefore, this approach considers explanatory variables as lagged variables of the variable to be forecasted. This approach does not have the need for data on numerous variables, but only for information directly related to the variable under analysis, which makes this method a relatively simple model. Access to historical information of the last 20 or 30 years is fundamental. While econometric models use multiple causal factors as explanatory variables, time series method uses lagged values of the same variable. A negative aspect of this method is that cause-effect relationship is not embodied in this approach (TERI Institute Web Page, 2006).

Time series methods or any econometric method are also subject to the same problem, when some variables are closely interrelated with another, which is called multi-collinearity. When a similar problem happens involving past values, this problem is called auto-correlation. This nature of problems requires a deep previous analysis to have acceptable adjustments before the completion of the model (TERI Institute Web Page, 2006).

Because of its characteristics, the most suitable appliance of Time Series Methods is to create short-term forecasts. In contrast, econometric models are more appropriate to long-term forecasts (TERI Institute Web Page, 2006).

Another variance of the time series method is the co-integration. The idea behind this approach consists in the fact that the relationship between any set of variables is expected to be maintained into the future. In other words, an implicit time-trend in the pattern of variables is considerably possible and economic variables are likely to perform in a similar manner in the long run, establishing causal effects on each other. A good example is the relation between per capita GDP and per capita consumption. Increasing per capita GDP, the per capita consumption is increased. If the per capita consumption is increased, the per capita GDP increases as well. This cycle leads to a conclusion that per capita GDP and per capita consumption have a tendency to vary according to the same patterns. Therefore, today, software modules address these matters to produce forecasts (TERI Institute Web Page, 2006).

4.2.7. Combinations of Methods

To maximize the attributes and address problems in a more complete way, combinations of theories can be made. To achieve even higher precision, a time series model and an econometric model can be combined to assure the presence of the dependency relationship of the first method and the causal relationship of the second method.

Alternatively, aiming to address physical and behavioral aspects in the same approach, an integration of econometric and end-use methods is also used procedure. The end use method supplies the model with an accounting framework for the sector's energy demands and the econometric approach supplies the model establishing the impact of factors such as GDP, price, and income on the results.

The National Energy Modeling System, a computer-based energy-economy modeling system of U.S. energy markets for the midterm period through 2025, uses this approach to project industrial energy demand as an arrangement of the energy-using technology and econometric estimates of actions (TERI Institute Web Page, 2006). The model embodies the impacts of energy prices on industrial energy consumption in terms of the efficiency of use of existing capital, the effectiveness of new capital, and fuels utilized. Energy conservation from technological change is also incorporated over time by trend-based curve.

Another good example that shows the usage of this combined procedure is the current forecast method developed by the State Utility Forecasting Group (SUFG) from Indiana, United States. This referred model constructs interactions among electricity cost, prices of energy and sales considering individual scenarios on a utility-by-utility basis.

The combination of Econometric and End-Use Methods provides tools to analyze trends of the energy consumption of all the three major consumer groups (residential, commercial, and industrial). Fuel prices and economic drivers are used as parameters to simulate variances in electricity demand. Therefore, the projections for each utility are made from a reliable set of statewide economic, demographic and fossil fuel price projections, and the forecasts point requirements such as peak demand, prices, and capacity (Indiana Electricity Projections, 2002).

4.3. Scenarios, Assumptions and Economic Activity Projections

4.3.1. Economic Activity Projections

One of the most significant influences in energy projection is the expansion of economic activity. Industrial Forecasting model projections are directly driven by economic activity projections which involve factors such as personal income, population, commercial employment and industrial output. As an illustration, SUFG bases its forecasting model in economic activity assumptions derived from other studies such as Indiana Macroeconomic Model developed by the Center for Econometric Model Research (CEMR), Indiana Business Research Center (IBRC) at Indiana University, and the Energy Information Administration (EIA) for the East North Central Region. SUFG takes into consideration CEMR's August 2002 projections for its base scenario, and a major input is a projection of total U.S. employment resultant from CEMR's model of the U.S. economy (Indiana Electricity Projections, 2002). In the same fashion, Demographic Projections are important parameters used by SUFG obtained from the Indiana Business Research Center. Additional fundamental economic projections are:

- Real personal income (the residential sector model driver).
- Non-manufacturing employment (the commercial sector model driver).
- GDP, GSP (gross state product) or similar regional indices.
- Electrical energy price.
- Demographic projections.
- Fossil fuel price projections (taken by EIA) – Since most countries in the world base their electrical production on fossil fuels, their prices and projections are

fundamental issues to load forecasting. Brazil can be considered an exception, having 85% of the electricity coming from hydroelectric plants.

- Natural gas prices.
- Utility price of coal.

4.3.2. Scenarios

Electric forecasts usually consider three different scenarios as a base of study: *the base scenario, the low scenario, and the high scenario.*

The *base scenario* is proposed to correspond to the most likely electricity forecast, considering that the forecast has an equal probability of being low or high. The *low scenario* is proposed to correspond to a reasonable lower bound on the electricity sales forecast and thus, has a low probability of occurrence. Finally, the *high scenario* is intended to characterize a possible upper bound on the electricity sales forecast and thus, has a low probability of occurrence (TERI Institute Web Page, 2006).

4.4. Electricity in the Industrial Consumer Class in Brazil

According to the 2004 National Energetic Balance made by the Ministry of Mines and Energy in 2003, from the total of 29.39 $x10^6$ tep of electricity consumed in Brazil, 46.9% of this number is consumed by the industrial segment. The residential sector responds for 22.3%, the commercial and public for 22.8%, the electricity industry for only 3.5% and the rest (agro industry and others) for only 4.5%. Also, 45.6% are consumed by the electrointensive industry, as shown in Table 4.1.

Table 4.1 Final Energy Consumption in Brazil - %

	1970	1980	1990	2000	2003
ELECTRICITY – 10^6 tep	3.41	10.55	18.71	28.51	29.39
Industry	49.2	55.6	51.6	44.2	46.9
From Which: Intensive Energy Consumption	44.1	45.8	49.1	45.4	45.6
Residential	21.1	19.0	22.4	25.2	22.3
Commercial and Public	22.0	19.7	19.3	23.1	22.8
Energetic Sector	5.2	3.4	3.1	3.2	3.5
Agro Business and Others	2.4	2.3	3.6	4.3	4.5

Source: Energetic Brazilian Balance Synopsis

In 2004, the industrial participation continued to grow if compared to the numbers obtained in the previous year. The industrial sector was responsible for 47.9% of the total electricity consumption. It is interesting to observe that the commercial and public sector surpassed the residential one showing an evident behavior of a developing country. It is also interesting to observe that the industrial electrical consumption in 2004 is lower than the industrial consumption of the 1970s and 1980s showing clearly when the industrialization process of the country happened.

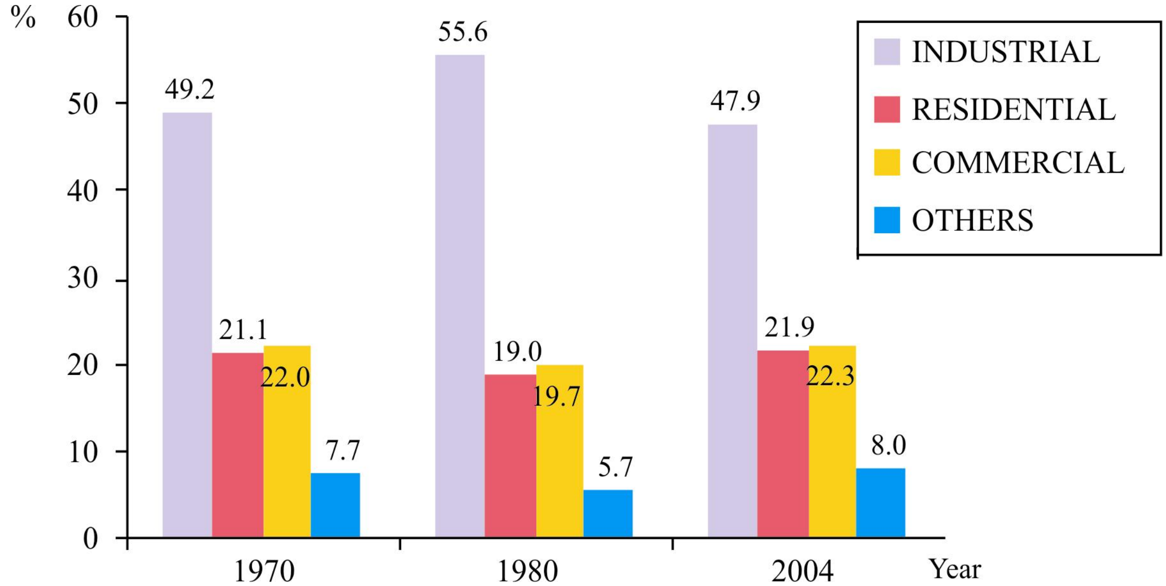


Figure 4.1 Electricity Consumption (%)

Source: Energetic Brazilian Balance Synopsis

The next figure shows the consumption of the total energy, from any source, illustrating again the importance of the industrial segment in Brazil. The values also demonstrate the considerable growth of the Brazilian industry in absolute numbers from 1970 to 2004.

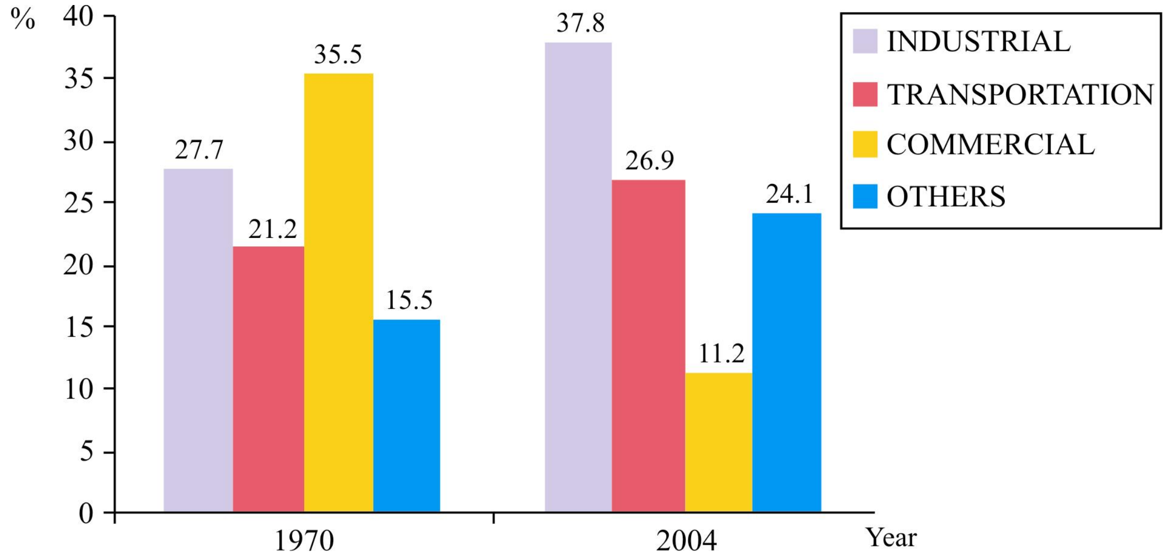


Figure 4.2 Final Energy Consumption (%) (Considering Any Source of Energy)

Source: Energetic Brazilian Balance Synopsis

Consequently, it is easy to conclude that although the industrial consumer class has different portfolios, large customers represent a highly significant portion to be analyzed. Therefore, it is usual to study electrointensive industry segment as a representation for the whole class. For that purpose, PacifiCorp, an electricity producer that has more than 8,400 megawatts of generation capacity in the United States providing more than 1.6 million customers with electricity, first classifies the industrial and other public customers' loads based on the Standard Industrial Classification (SIC) code, separating businesses per types, and sizes, separating larger electricity users and smaller electricity users. Then, PacifiCorp maintain a straight connection with these larger electricity users in order to get strategic and operational information and analyze industries trends that will be fundamental input for load forecasting. In a long-term sense, economic and demographic information are essential data for PacifiCorp as well. The facility adopts different methods for developing forecasts with different time projections. Near term projections are obtained from statistical time series and regression methods while long-term forecasts are dependent on end-use and econometric modeling techniques. This methodology also analyzes separately each state where the PacifiCorp has activities (PacifiCorp, 2004).

A much smaller company, but as effective example, the city of Burlington Electric Department (BED) provides electricity for 16,000 residents, 2,845 small business customers which consume less than 3,000 kWh per month, 784 large business customers that consume more than 3,000 kWh per month, and Burlington International Airport. BED separates their market into three classes separately analyzed: residential, commercial/industrial, and street lighting. BED´s commercial and industrial sales represent 72% of the total sales (Burlington Electric IRP, 2004). The method used by this company is based on explicit estimation of the historical reaction of the electricity consumption to socioeconomic factors such as income, employment rate, electricity prices, weather and others. The procedure considers the customer class load shape and fit the sales prerequisite as forecasted to these class load shapes. The supposition is that the load shapes will not be modified over the forecast time perspective (Burlington Electric IRP, 2004).

Figure 4.3 represents BED's monthly megawatt hour sales for the years of 1985 to 2003.

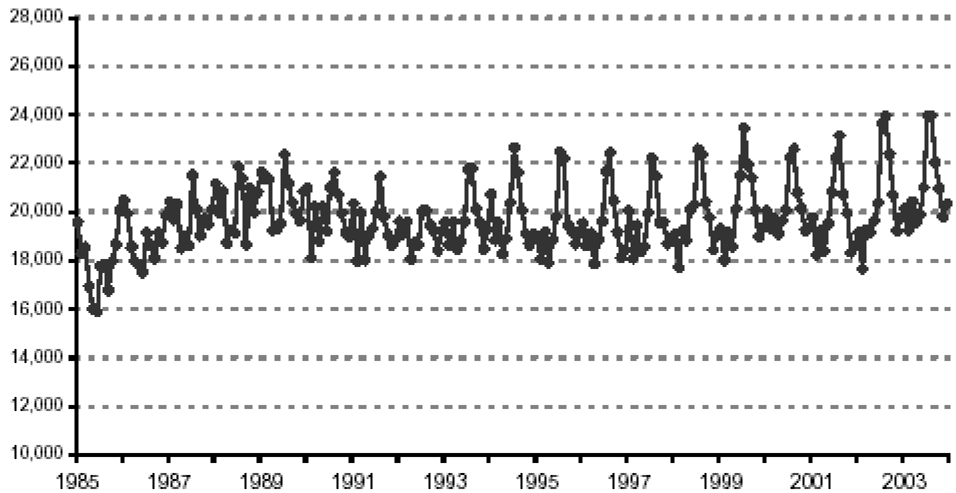


Figure 4.3 Commercial/Industrial Monthly Sales of Burlington Electric Department

Font: Load Forecast – Burlington Electric Department

The model also aggregates energy efficiency, activities of large accounts such as GE, and as said before, economic conditions. The model considers employment rate as a measure for economic health. Regression statistics is the mathematical tool used. Table 4.2 shows an example of their model's results (Burlington Electric IRP, 2004).

Table 4.2 Commercial and Industrial Sales Model

Variable	Coefficient	Std Err	T-Statistic
Constant	–10,180,963.38	1,873,012.34	–5.44
Days	497,507.00	41,042.61	12.12
CDD	6,443.61	310.78	20.73
HDD	2,777.58	143.67	19.33
ESH_DSM	–1.18	0.113	–10.39
Employment	258.52	38.19	6.77
Real Electric Price (1982$)	–126,232.99	62,540.25	–2.02
Key Accounts	23.26	2.38	9.76
Lag Key Accounts	6.99	2.03	3.45

Regression Statistics	
Observations (1/1986-12/2003)	210
Adjusted R-Squared	0.914
Durbin-Watson Statistic	1.74
Mean Abs. Dev. (MAD)	298,142.6
Mean Abs. % Err. (MAPE)	1.51%

Source: Load Forecast – Burlington Electric Department

4.5. Electricity Demand Forecasting in Brazil

Demand for electricity has conditioning factors which coexist and interact in two qualitative levels. The first one is the macrostructure level which can be exemplified by government policies for development. The second level is made of internal factors and is characterized by the collection of activities which consumes energy through equipment and machines.

Any method for dimensioning future electrical energy demand is directly impacted by regional particularities. Types of economic activities, socio-economic level of the population, degree of development, infrastructure and other aspects intrinsic of a region, a state or a country are fundamental factors for electricity forecasts. As a result, considering that Brazil is a developing nation, some particular issues that establish the socio-economic profile and its behavior through time must be addressed in this study. Also, the heterogeneity of social, economical, cultural aspects and infrastructure differences along the several Brazilian states make the task even more complex. According to Barbosa and Leal, the Brazilian electrical industry presents unique characteristics which differentiate it from any other one in any other country. An evident difference is the way chosen to generate electricity, essentially based on hydroelectric plants. From the total installed capacity, 85% of the electrical energy comes from hydroelectric sources.

However, not forgetting these individualities, in any place including Brazil, as a fundamental premise, it can be seen that electrical energy demand is due to some aspects such as the socio-economic circumstances, infrastructure, personal income, cultural standards, and consuming habits. Therefore, in order to find applicable data to develop electricity demand forecasts, it is necessary to transform these variables from the social-economic scenario in a quantitative format and also consider in the model quantitative data extracted from big economic groups.

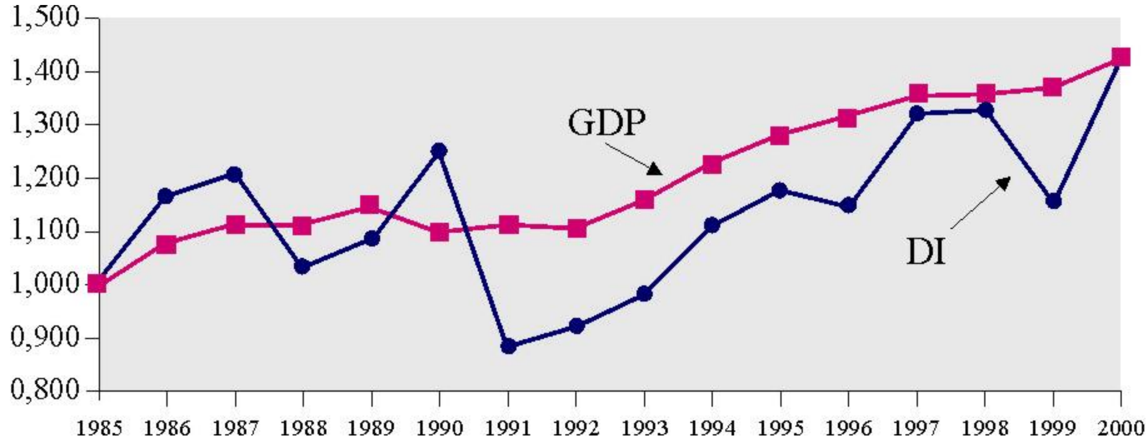
Azevedo, Niemeyer and Santos (2001) proposed an electrical energy forecasting methodology directed to the main electrointensive industrial consumers and adopted by the Brazilian Technical Committee for Market Studies (CTEM) and the Coordinator Committee of the Expansion Planning of the Electrical Systems (CCPE), directly linked to the Mines and Energy Ministry (MME) of the country. The sectors considered in the study are the industries of ironwork, aluminum, iron joints, soda-chloride, paper, cellulose, petrochemistry, cement, and copper. The approach adopted by this forecasting methodology is based on alternative macroeconomic scenarios picturing the progression of the economy; population growth and householding usage.

The elemental equation used is given by:

Physical Production = Internal demand – Importation + Exportation.

The internal index of GDP growth represented by the *income elasticity of the electrical energy consumption index* determines the internal demand. Future values of the income elasticity are predicted using hypothesis of future penetration of many products in the market, considering its historical behavior and per capita consumption. To estimate importations and exportations, a dynamic perspective of the Brazilian market and the international market is analyzed particularizing products and market penetration. Finally, the consumption of electricity is obtained based on the physical production considering the specific consumption characteristic of each productive process.

The Tables 4.3, 4.4 and 4.5 and Figures 4.4, 4.5 and 4.6 are examples that demonstrate some of the results:



red line = Internal Demand (DI) blue line = GDP

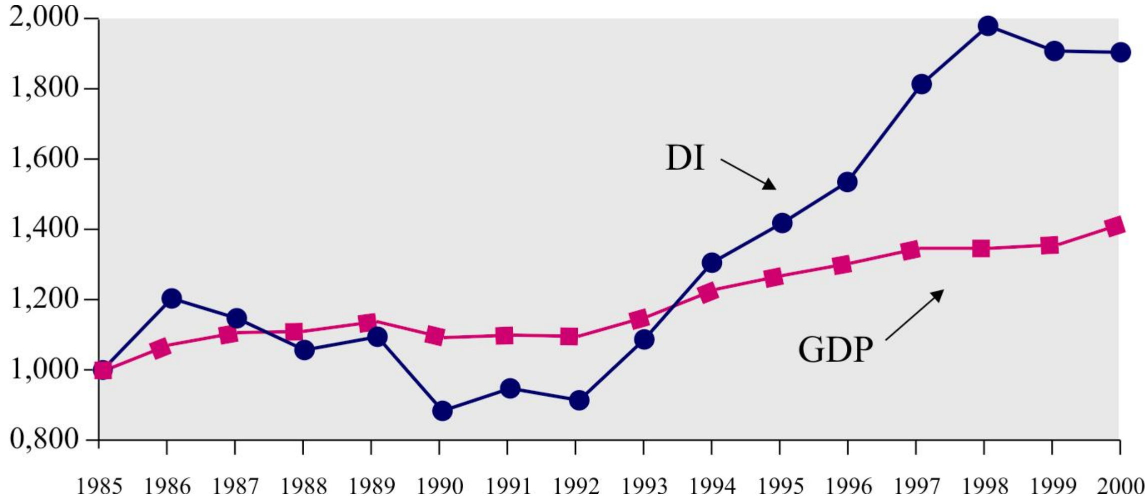
Figure 4.4 Brazilian GDP and Internal Demand for the Ironwork Industry

Source: Azevedo, Niemeyer, Santos (2001)

Table 4.3 Brazilian GDP and Internal Demand for the Ironwork Industry

Period	Average Growth (%)		*income elasticity Index*
	DI	GDP	
1985-2000	2,38	2,38	1,00
1992-1997	7,52	4,18	1,80

Source: Azevedo, Niemeyer, Santos (2001)



red line = Internal Demand (DI) blue line = GDP

Figure 4.5 Brazilian GDP and Internal Demand for the Aluminum Industry

Source: Azevedo, Niemeyer, Santos (2001)

Table 4.4 Brazilian GDP and Internal Demand for the Aluminum Industry

Period	Average Growth (%)		*income elasticity Index*
	DI	GDP	
1985-2000	4,41	2,38	1,89
1992-1997	12,59	3,23	3,90

Source: Azevedo, Niemeyer, Santos (2001)

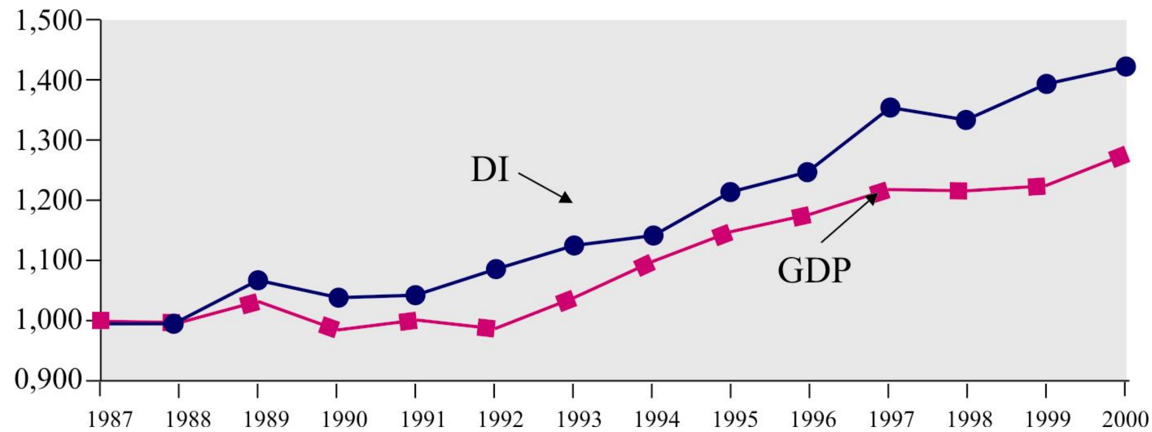


Figure 4.6 Brazilian GDP and Internal Demand for the Soda-Chloride Industry

Table 4.5 Brazilian GDP and Internal Demand for the Soda-Chloride Industry

Period	Average Growth (%)		*income elasticity Index*
	DI	GDP	
1985-2000	2,76	1,91	1,45
1992-1997	2,33	1,92	1,22

Source: Azevedo, Niemeyer, Santos (2001)

The example above makes clear the correlation between electricity demand and economic activity represented by the GDP that is embodied in the income elasticity index used in the model.

Additionally, Souza (1999) proposes two models for electricity demand forecasting for Eletronort, a Brazilian facility located in the Brazilian northern area: The models base their configuration in factors such as *urbanization level*, *population growth*, *habitants per house*, *attendance index* (urban and rural), *income elasticity of the electrical energy consumption index* and *average residential consumption* to establish socio-economic tendencies related to energy utilization. Also considered in the models is a typical developing country element called *consumption structure* which takes into account the perspectives of developing the production structure in the region, state, or country. Another interesting element used is the number of residential consumers divided by the number of houses with electrical energy. As the northern region of the country is the least developed in the country, there are still a considerable number of clandestine consumers, especially in the Amazon forest, which makes this number considerably important to the studies.

The first model developed constructs hypotheses of population growth, urbanization level, inhabitants per house, attendance index, houses per consumer factor, average residential consumption and consumption structure to obtain the forecast of energy consumption. The parameters are obtained by a regression assuming S curves, logistics and reciprocal functions. The forecaster assumes a saturation value. Graphics are made based on Fresid, using past values of each factor and projections for the future tending to a saturation value. After that, linear regressions are made to obtain the future parameters (Some of them are transformed through the logarithm of the original function) (Souza, 1999).

Some examples of the results are shown on Figures 4.7, 4.8 and 4.9:

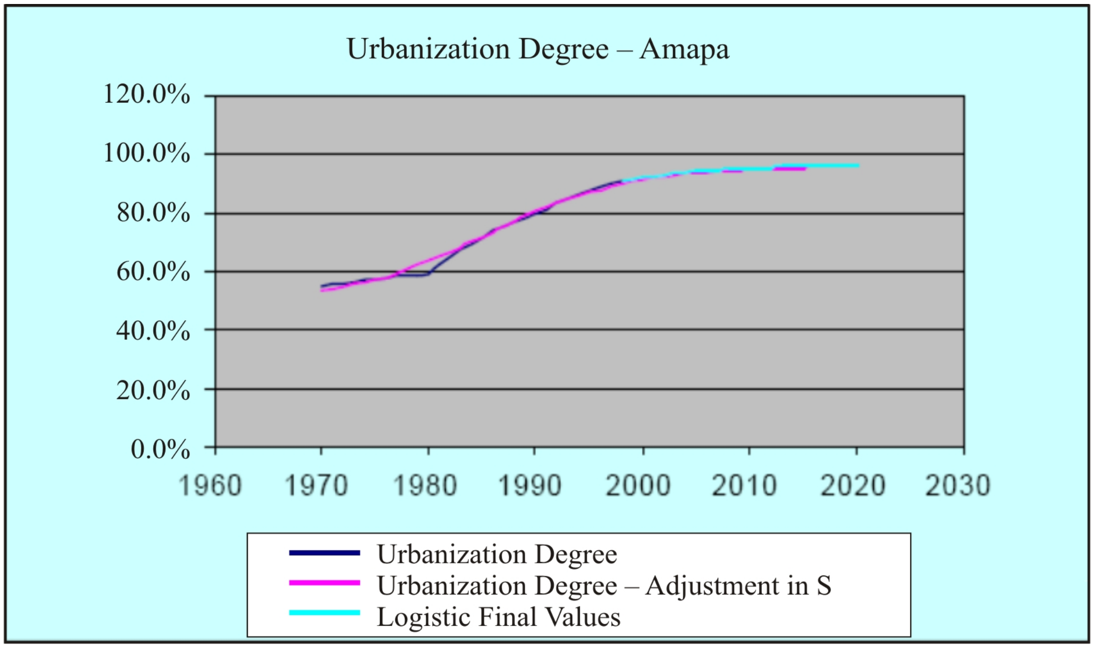


Figure 4.7 Urbanization Degree – Amapá

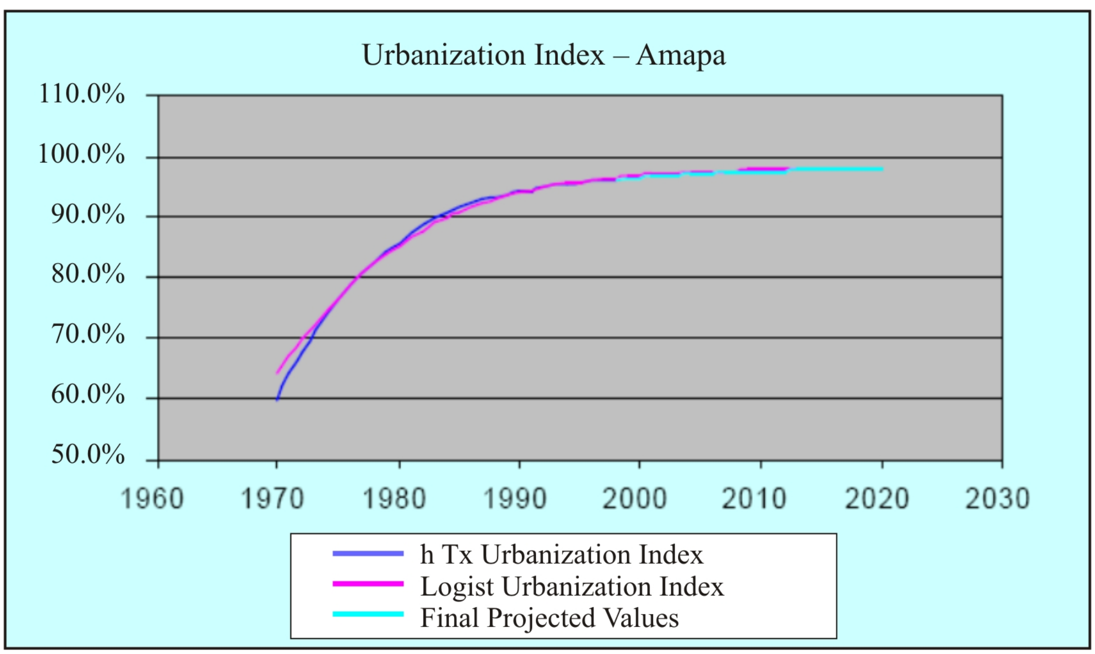


Figure 4.8 Urbanization Index

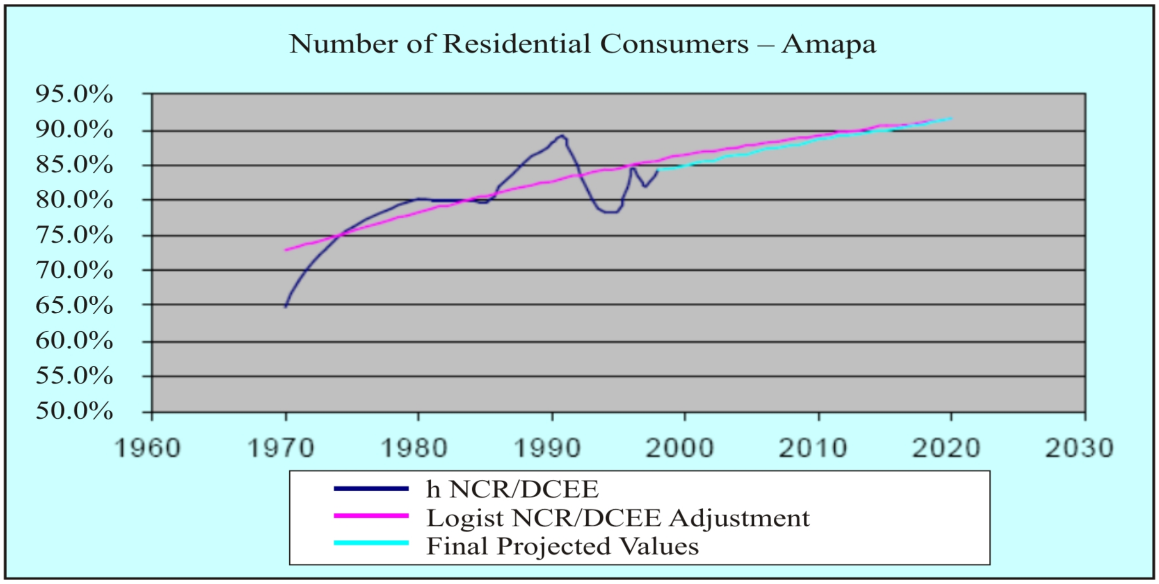


Figure 4.9 Number of Residential Consumers

The other model is based on the GDP growth that will impact the electrical energy demand. The reference used is the *income elasticity of the electrical energy consumption* which represents the tendency to use more energy when obtaining a higher income. The *income elasticity of the electrical energy consumption* is the relation between the electrical energy demand growth and the economy growth represented by the GDP. These values are obtained by historical data to project scenarios.

ELASTTREND = Electrical Energy Demand Growth / GDPgf

After attaining this value, the total consumption series is obtained from this equation:

$$TC_i = TC_{i-1}\left(ELASTREND_I \otimes GDP\right)$$

total consumption = TC

ELASTREND = income elasticity of the electrical energy consumption

GDP= GDP growth

It is interesting to notice that this method is highly impacted by new technologies inserted in the industrial consumer segment and into the residential segment, consequently this module is especially consistent to the macrostructure level. So, observing these modules proposed by Souza (1999), it is evident the importance of particularizing forecasting studies. Singular social, economical, and cultural characteristics of different regions are important variables to be considered taking each study to different assumptions and conclusions.

4.6. Current Methods Evaluation

After analyzing the methods currently used in the electric industry, in a general way, it is possible to state that although some progress has happened, the demand forecasting models are still very simple. The big majority of companies still base their forecasting methodology on energy consumption trends straight-line extrapolations. These models consider demand as only a function of time assuming that past temporal behavior will be maintained in the future. These models are limited in their ability to explain demand since they do not consider determinant variables other than time and do not capture effects of business cycles expansions and recessions.

Chapter 5

Proposed Methodology for Industrial Load Forecasting at a Distribution Utility

5.1. Statistical Analysis of the Electric Load Consumption Data

The case of study which has provided all the data and support is CPFL Energy S/A (Companhia Paulista de Força e Luz), one of the most important electricity companies in Brazil. CPFL Energy is a holding company that controls companies and private enterprises in the generation area, electric power distribution and commercialization. This holding company is one of the largest private companies of the Brazilian electric sector, acting in the regulated market and in the free market as well. CPFL Energy runs companies that act mainly in the most developed state of the country, Sao Paulo, with a highly demanding public. Their customers include high technology conglomerates, fine chemistry industries, alcohol producers, metallurgical and automobile industries, paper and cellulose and other intensive electricity consuming industries. In the distribution area, CPFL Energy drives three distinct companies operating in different physical areas: the CPFL Paulista, the CPFL Piratininga and the Rio Grande Energy S.A.

Aiming to have an objective study showing a clear relationship of the company and its consumers, it was decided to restrict the study to one of these companies. Therefore, CPFL Paulista was chosen to be studied. In August 2006, CPFL Paulista was considered the best electric power distributor of Brazil, a prize conceded by the Brazilian Association of

Electric Power Distributors (Abradee). One year before, the company had already earned the "Premio Nacional de Qualidade" (PNQ) prize of managerial quality, conceded by the National Foundation of the Quality.

CPFL Paulista is responsible for supplying a very important market inside the state of Sao Paulo, being in charge for meeting a high demand. The company operates in the residential, commercial, public and industrial segments among others as can be seen in the Table 5.1 and Figure 5.1.

Table 5.1 CPFL Paulista Region Annual Consumption (KWh)

Year	Total	Residential	Commercial	Industrial	Rural	Public Power	Public Illumination	Public Services	Own Consumption
1990	12.366.261	3.301.001	1.409.840	5.484.205	712.758	284.150	536.634	611.777	25.896
1991	13.124.448	3.570.802	1.501.092	5.746.919	758.074	315.412	549.491	654.524	28.134
1992	13.440.041	3.681.558	1.538.391	5.879.151	712.138	348.663	567.422	684.556	28.163
1993	14.293.338	3.853.725	1.637.409	6.421.431	710.277	351.766	582.118	711.427	25.184
1994	14.940.000	4.074.526	1.740.655	6.644.050	734.628	367.769	595.079	756.137	27.157
1995	15.606.319	4.535.849	1.938.314	6.549.611	749.807	400.472	616.030	789.500	26.736
1996	16.596.496	4.888.459	2.118.827	6.915.369	753.968	433.588	645.290	811.117	29.878
1997	17.903.289	5.213.589	2.359.786	7.470.559	849.940	470.546	673.497	835.463	29.909
1998	18.588.399	5.463.934	2.580.619	7.634.890	847.776	484.743	688.557	859.365	28.515
1999	19.041.661	5.521.083	2.689.134	7.839.033	888.613	487.842	697.049	890.603	28.304
2000	20.246.902	5.772.516	2.988.355	8.408.329	872.947	526.625	711.274	930.405	36.451
2001	18.386.194	4.850.921	2.661.810	8.070.946	779.334	449.169	630.758	911.430	31.826
2002	18.206.358	4.807.824	2.771.826	7.828.059	773.076	438.683	627.255	929.323	30.311
2003	19.137.714	5.034.001	2.949.898	8.196.774	850.721	450.597	663.823	972.562	19.339
2004	18.952.443	5.154.586	3.124.268	7.634.097	900.007	468.694	673.771	978.487	18.533

Source: CPFL Database

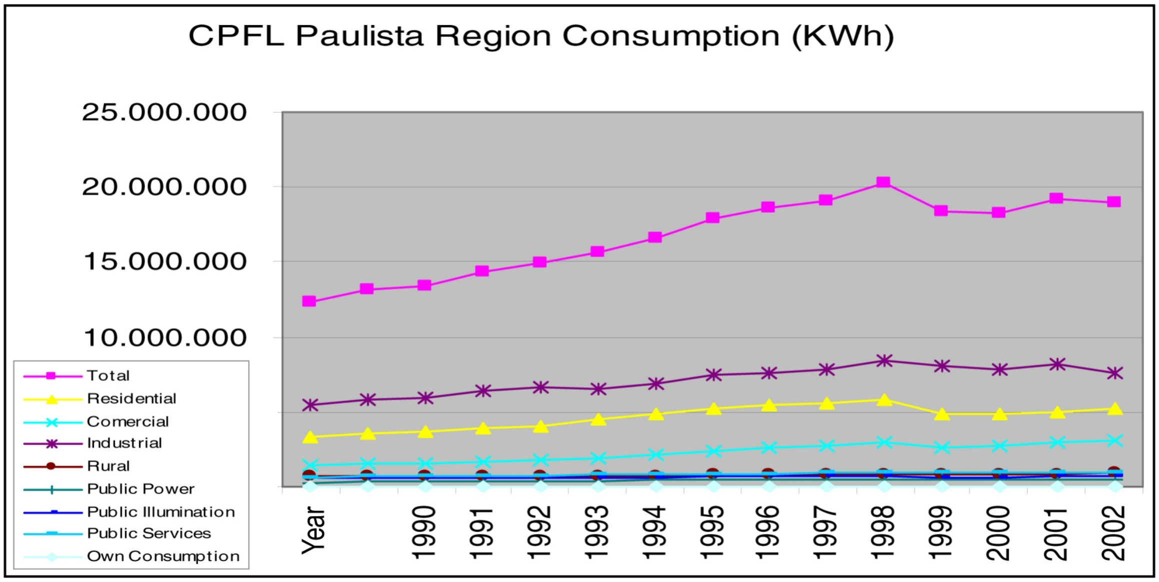


Figure 5.1 CPFL Paulista Region Consumption (KWh)

The industrial segment is the most important one, responsible for more than forty percent of the total, as shown in Table 5.2 and Figure 5.2.

Table 5.2 CPFL Paulista Region Annual Consumption (%)

Ano	Residential	Comercial	Industrial	Rural	Public Power	Public Illumination	Public Services	Own Consumption
1990	26.69	11.40	44.34	5.76	2.29	4.33	4.94	0.20
1991	27.20	11.43	43.78	5.77	2.40	4.18	4.98	0.21
1992	27.39	11.44	43.74	5.29	2.59	4.22	5.09	0.20
1993	26.96	11.45	44.92	4.96	2.46	4.07	4.97	0.17
1994	27.27	11.65	44.47	4.91	2.46	3.98	5.06	0.18
1995	29.06	12.42	41.96	4.80	2.56	3.94	5.05	0.17
1996	29.45	12.76	41.66	4.54	2.61	3.88	4.88	0.18
1997	29.12	13.18	41.72	4.74	2.62	3.76	4.66	0.16
1998	29.39	13.88	41.07	4.56	2.60	3.70	4.62	0.15
1999	28.99	14.12	41.16	4.66	2.56	3.66	4.67	0.14
2000	28.51	14.75	41.52	4.31	2.60	3.51	4.59	0.18
2001	26.38	14.47	43.89	4.23	2.44	3.43	4.95	0.17
2002	26.40	15.22	42.99	4.24	2.40	3.44	5.10	0.16
2003	26.30	15.41	42.83	4.44	2.35	3.46	5.08	0.10
2004	27.19	16.48	40.28	4.74	2.47	3.55	5.16	0.09
Avg (%)	27.75	13.34	42.69	4.80	2.49	3.81	4.92	0.16

Source: CPFL

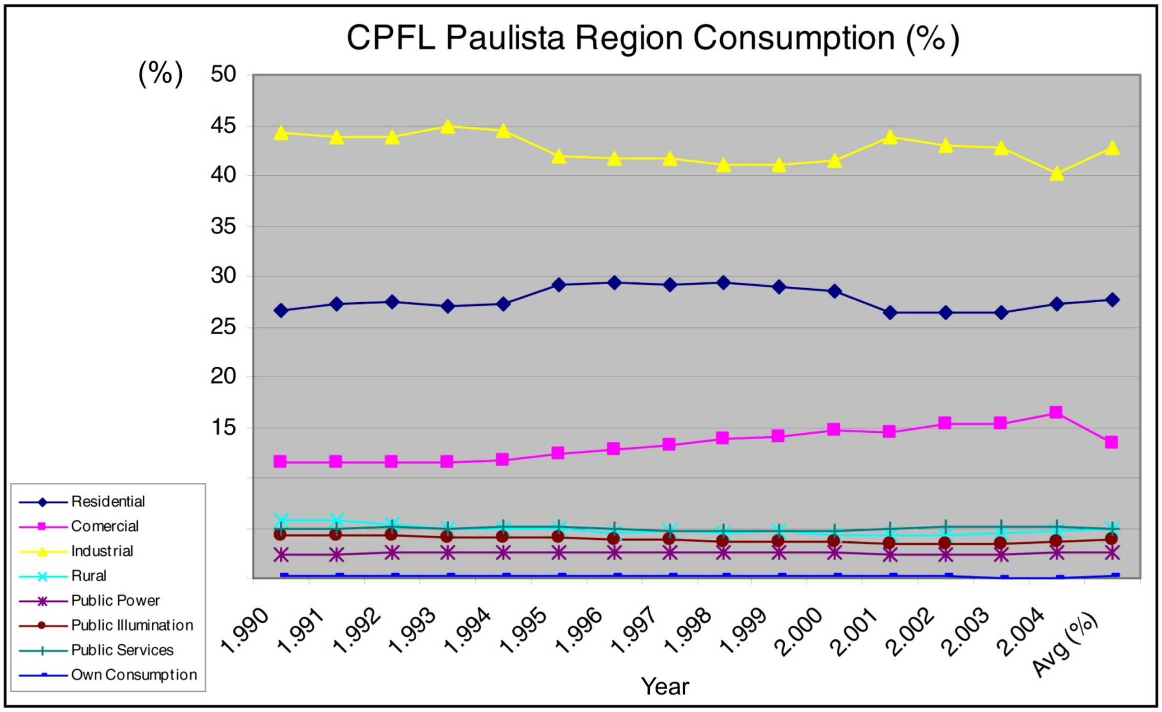


Figure 5.2 CPFL Paulista Region Consumption (%)

Being a developing country, Brazil has high rates of economic growth. As a consequence, economic growth means industrial growth and more need for electricity, as can be seen in Figure 5.3. From 418.819 MWh in January 1990, the CPFL Paulista concession area demand grew to 637.893 MWh in December 2004.

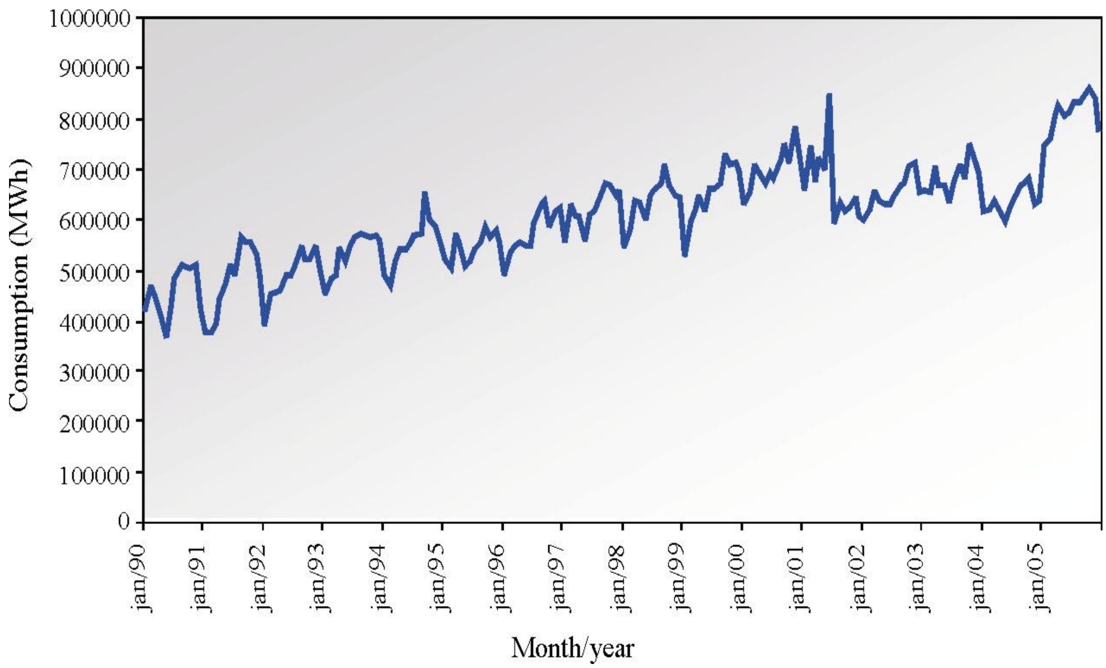


Figure 5.3 Industrial Consumption Historical Series

Source: CPFL

An interesting observation from Figure 5.4 is that although the industrial demand has been growing according to the economy growth, the percentage of industrial demand stays considerably stable compared to the total demand. This is explained due to the fact that other segments are growing as well. According to Lacerda (2005), the current stage of the Brazilian economy predisposes room for growth in all the economic sectors, especially the service one. This room for growth signifies a high growth index.

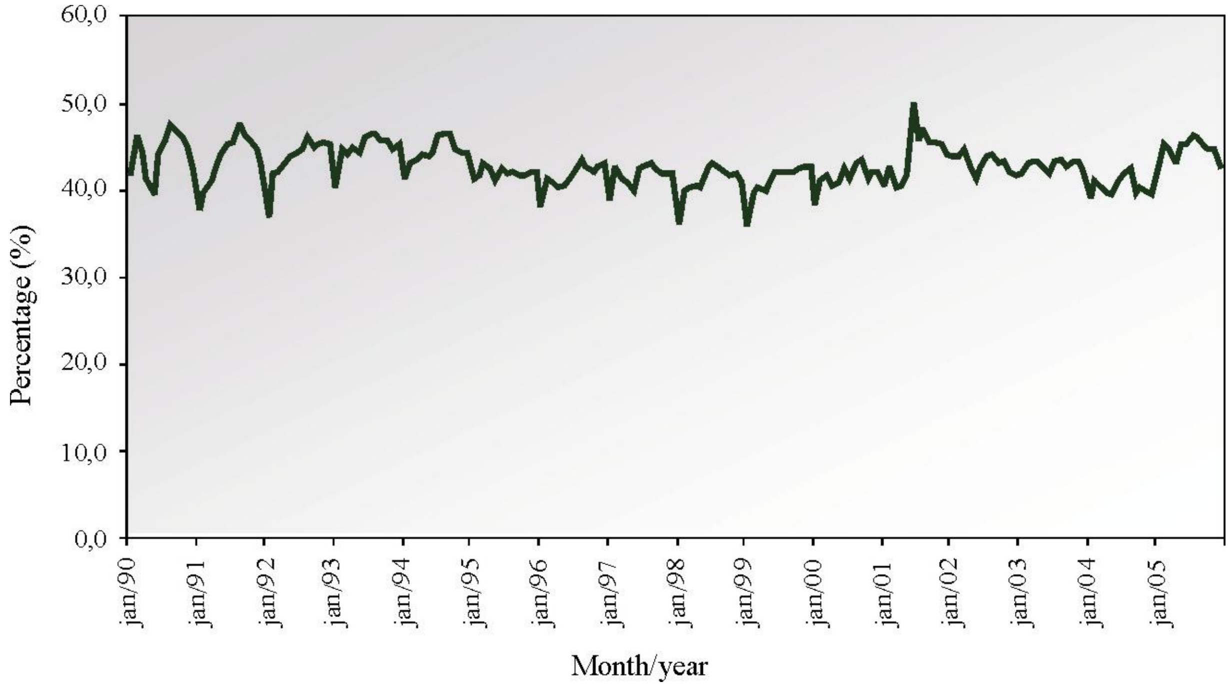


Figure 5.4 Percentage of Industrial Consumption Compared With Total Consumption

Source: CPFL

5.2. The Forecasting Approaches

5.2.1. The First Approach

The main idea of the study is to analyze the electricity industry under a supply chain management perspective. Therefore, to perform this study, CPFL Paulista supply chain was analyzed and data from its industrial customers was raised.

As already discussed in Chapter 3, the behavior of electricity demand trends is clearly connected to economic performance. Therefore, intending to establish a direct relationship between the industrial electricity demand and economic explanatory variables, a study was performed for developing a mathematical model. The model's final goal is accurately predicting future electricity demand for CPFL Paulista Utility.

The first idea was to separate CPFL Paulista´s industrial consumers by the type of activity. The approach selected six industrial segments responsive for consuming 67.99% of the total energy sold by the company to the industrial customers. The segments are listed in the next table:

Table 5.3 Industrial Segments

Industrial Segments	Consumption (%)
Food Industry	17.68
Textile	16.77
Metallurgy	10.56
Mechanical	6.38
Chemical	7.42
Paper & Cardboard	9.16
Sum (%)	67.99

From these six industrial segments, the approach uses the monthly consumption historical data analyzed together with economic explanatory variables to build a model.

However, due to not having enough recent consumption data of the segments, this approach was abandoned.

5.3. The Second Approach

The second approach keeps studying the electric market under a supply chain Management perspective focusing on the consumer side of the chain. The major difference is that the second method deals in its majority with variables in the macroeconomic level. So, after studying the consumers and isolating the industrial segment to better understand its environment, the new methodology identified explanatory variables aiming to establish a relationship among them and the company's total industrial electric sales. Finally, the step wise regression model selected the significant variables to build a reliable electricity demand mathematical forecasting model for the company.

5.3.1. Selection of the Explanatory Variables

Once CPFL is one of the largest electricity suppliers in the state of Sao Paulo which is industrially the most important state of the country, it is easy to conclude that macroeconomic variables from this state and from the country would be good indicators to explain the behavior of CPFL's consumers. So, the explanatory variables chosen to be tested were mostly macroeconomic variables related to the Brazilian national economy, or to the economy of the state of Sao Paulo and consequently correlated to CPFL's electricity sales. Some variables are indexes that represent the production of important industrial consumer sectors, and others are variables that can impact industrial production and consequently, electricity sales. Most of them are macroeconomic indexes. The explanatory variables are listed in Table 5.4:

Table 5.4 Explanatory Variables

Regression Model	$Y = B + B_1X_1 + B_2X_2 + \ldots + BnXn$
Parameters	
y	Industrial Electric Consumption Inside the Paulista Concession Area
x_1	Production – High Electric Intensity Industries
x_2	Production – Median electric Intensity Industries
x_3	Production – Low Electric Intensity Industries
x_4	CDD (temperature variation index)
x_5	Industrial Production (Paulista) – Production Index in the Paulista Area
x_6	Industrial Production (Brazil) – Production Index in the Country
x_7	Industrial Production (Sao Paulo) – Production Index in the state of Sao Paulo
x_8	Actual Days (dias faturados) – Actual Number of Days in the Month
x_9	(t-1) – demand of the month t -1(Last Month)
x_{10}	(t-12) – Demand Observed a Year Before
x_{11}	GDP Billions (Reals)
x_{12}	IGPM Inflation Index
x_{13}	IGP-DI Inflation Index
x_{14}	SELIC – Interest Rate %
x_{15}	SELIC (year) – Yearly Interest Rate %
x_{16}	Dollar Rate (Buying Price in Real)
x_{17}	IBOVESPA/1000 – Market Share Index
x_{18}	Industrial Production – Paper and Cellulose
x_{19}	Industrial Production – Basic Metallurgy
x_{20}	Industrial Production – Plastic/Rubber
x_{21}	Industrial Production – Edition and Impression
x_{22}	Industrial Production – Food

Industrial production data represent important explanatory variables. Some of them, such as the *Industrial Production (Paulista)* (x_5), *Industrial Production (Sao Paulo)* (x_7), *and Industrial Production* (Brazil) (x_6) were used with the prospect of directly reflecting trends in energy demand**.** Additionally, being a supplier of raw material for many fields of the industrial segment, the variable *Industrial Production – Basic Metallurgy* (x_{19}) was chosen as a predictor of the rest of the industrial segment behavior and, consequently, their electric demand. Also supposing an anticipation behavior because of supplying packing industries, *Industrial Production – Paper and Cellulose* (x_{18}), *Industrial Production – Plastic/Rubber* (x_{20}), and *Industrial Production – Edition and Impression* (x_{21}) (used for labors) were used as well. Food industry was chosen for being an important consumer segment to CPFL Paulista sales. All the industrial production data collected came from IBGE institute. The kind of index used was the Index of monthly fixed base without seasonal adjustment (Base: Average of 2002 = 100).

Other important explanatory variables are the macroeconomic variables which are indicators of the entire economy. As explained in Chapter 3, macroeconomics considers the importance of big aggregates making possible the examination of the economy of states, countries or even the world economy. Consequently, these aggregates correspond to important indexes for measuring the economy and, consequently, can be linked to energy consumption. GDP (x_{11}) is measured in billions of reals; *IGPM* (x_{12}) and IGP-DI(x_{13}) are both inflation indexes; *Dollar Rate (Buying Price)*(x_{16}) is the dollar price paid in Real; and *IBOVESPA/1000 – Market share index*(x_{17}) is the market share index for the BOVESPA market. These macroeconomic explanatory variables were taken from IBGE institute. The information about interest rates came from Brazilian Central Bank and the *SELIC – interest rate %* (x_{14}) is the Brazilian interest rate in a monthly base, and *SELIC (year) – yearly interest rate %* (x_{15}) is the Brazilian interest rate in a yearly base.

Considering that future electrical consumption could have a strong relation with past consumption values, two explanatory variables were created to verify this idea: *(t-1) – demand of the month t -1*(x_9) based on values belated in one month compared to the dependent series; and *(t-12) – demand observed a year before* (x_{10}) – based on values belated in one year compared to the dependent series. *Actual Days (dias faturados) – actual number of days in the month*(x_8) represents the real number of days the company sells electricity in a particular month. For example, in February 2004 there were 29 actual days and in December 2005 there were 31 actual days.

Other variables are industrial production indexes which classify industries according to the intensity of electricity consumption. So, *Production – High electric Intensity Industries* (x_1), *Production – Median electric Intensity Industries* (x_2) and *Production – Low electric Intensity Industrie*s (x_3) are respectively industrial consumption indexes of companies that intensively consume electricity, that consumes electricity in a moderate way, and that consume a low amount of electricity.

To consider environmental aspects in the model, the variable *CDD (temperature variation index)* (x_4) was considered as well.

It is interesting to notice that some units were modified to approximate values among different variables. Dollar price was multiplied by ten, and the IBOVESPA index was divided by one thousand (see Tables A-1 in Appendix) to make numbers closer and allow an easier visual graphic comparison.

5.3.2. The Stepwise Regression Procedure

With the intention of generating a consistent model to predict electricity demand, a linear regression methodology was used. According to Meiri and Zahavi (2005), Regression models attend the form:

$Y = \beta_0 + \beta_1 x_1 + \ldots + \beta_m x_m + \varepsilon$,

Where:

Y: Dependent variable

β: Coefficient

x: Independent variables

m: Number of independent variables

ε: Residues

Linear regression is used to forecast the value of a continuous dependent variable by means of a host of predictors. The major problem of linear regression models is the fact that the number of potential predictors explaining a response could be very large. The major difficulty in developing large scale linear regression models is to select the most influential variables, eliminating all the irrelevant and redundant variables. So, the problem presents two contradictory concerns: the prediction accuracy often determined by the variance of the prediction error, and the prediction bias associated when applying the model results on a new set of data. As more predictors are introduced to a model, model accuracy usually improves, but the bias may get worse. Therefore, the Stepwise method is a tool to perform a tradeoff analysis between accuracy and bias necessary to find the best combination of dependent variables for a model (Meiri and Zahavi, 2005). Each time a new variable is added to the model, the significance of each of the variables already in the model is re-examined, making possible an efficient selection. The Statistica Program was the tool used, and calibration of the model considers the inclusion of the intercept in the model, and on P (F>Fo) = 0.05.

5.3.3. Selection of the Calibration Period and the Validation Period from Historical Observations

The explanatory variables chosen for the study were the ones listed in Table 4.2.2. As exposed in Table A-1 (appendix), historical series from January 2001 to December 2005 were applied. Due to difficulties of finding the real value, the *Industrial Production – BasicMetalurg;, Industrial Production – Paper and Cellulose; Industrial Production – Plastic/Rubber; Industrial Production – Edition and Impression;* and *Industrial Production – Food* values for December 2005 were obtained by multiplying the value of December 2004 by the growing index referent to the months of November and December. The calibration period uses data from January 2001 to December 2004. The year of 2005 is used in the Validation Period. The Statistica Program was the tool used, and the model considers the inclusion of the intercept, and P (F>Fo) = 0.05.

5.3.4. The First Regression Model

The first regression model was developed containing all the explanatory variables listed in Table 5.4. Figure A.1 (appendix) shows the spreadsheet used to perform the linear regression in the Statistica Program.

The first regression presented the following Summary for Dependent Variable:

Table 5.5   First Regression Model Results

N=40	Regression Summary for Dependent Variable: Total Consumption R= ,98189547 R²= ,96411871 Adjusted R²= ,91768410 F(22,17)=20,763 p<,00000 Std.Error of estimate: 17,089					
	Beta	Std.Err. of Beta	B	Std.Err. of B	t(17)	p-level
Intercept			-114,945	209,5898	-0,54843	0,590529
x_1 (High Intensity)	0,99119	0,568508	8,793	5,0433	1,74349	0,099302
x_2 (Medium Intensity)	1,09101	0,644090	8,514	5,0262	1,69388	0,108529
x_3 (Low Intensity)	0,67553	0,882507	4,409	5,7598	0,76546	0,454492
x_4 (CDD)	0,11375	0,096503	0,181	0,1534	1,17875	0,254733
x_5 (Ind. Paulista)	0,60348	0,601865	3,594	3,5848	1,00268	0,330074
x_6 (Ind. Brazil)	-3,19201	1,751593	-23,398	12,8394	-1,82234	0,086042
x_7 (Ind. State of Sao Paulo)	1,09254	0,698025	6,696	4,2780	1,56519	0,135961
x_8 (Actual Received)	0,04197	0,066657	3,038	4,8240	0,62969	0,537270
x_9 (t-1)	0,00823	0,192383	0,000	0,0002	0,04277	0,966387
x_{10} (t-12)	0,17939	0,088297	0,000	0,0001	2,03169	0,058118
x_{11} (GDP)	0,44746	0,263903	1,544	0,9106	1,69556	0,108204
x_{12} (IGPM)	-0,19270	0,350561	-9,720	17,6828	-0,54969	0,589681
x_{13} (IGP-DI)	0,23016	0,262993	11,319	12,9342	0,87514	0,393695
x_{14} (SELIC %)	0,17413	0,098698	31,706	17,9719	1,76422	0,095654
x_{15} (SELIC % (year))	0,02326	0,142589	0,394	2,4157	0,16311	0,872356
x_{16} (Dollar Price)	0,19894	0,201571	32,034	32,4585	0,98693	0,337515
x_{17} (IBOVESPA Index/100)	0,50661	0,374458	5,247	3,8784	1,35292	0,193800
x_{18} (Ind. Paper and Cellulose)	-0,42796	0,285832	-2,967	1,9814	-1,49724	0,152667
x_{19} (Ind. Basic Metallurgy)	-0,09688	0,204585	-3,018	6,3735	-0,47353	0,641860
x_{20} (Ind. Rubber and Plastic)	-0,36072	0,202798	-30,752	17,2893	-1,77869	0,093177
x_{21} (Ind. Printing)	0,23621	0,156258	337,535	223,2860	1,51167	0,148983
x_{22} (Ind. Food)	-0,23093	0,183203	-14,294	11,3396	-1,26053	0,224505

Observing Table 5.5, it is possible to see that the model demonstrates high general accuracy considering several indicators. The R^2 value is equal to 0.96411871 and adjusted R^2 value is equal to 0.91768410, both very close to 1.00. Additionally, the p value<0.00000, is very close to zero which shows good significance. Moreover, the value of F(22,17)=20,763 confirms good model precision . Consulting Table 4.7 (Appendix), Fo = 2.21, < F(22,17)=20,7. Consequently, the value F(22,17) shows a high significance index for the model.

Although the model has indications of good accuracy, the model shows deficiencies concerning the significance of each explanatory variable. At first, the Statisca program demonstrated that none of the explanatory variables were significant for the model. Figure 5.5 illustrates that none of the variables are highlighted in red color (significant variables would be highlighted in red).

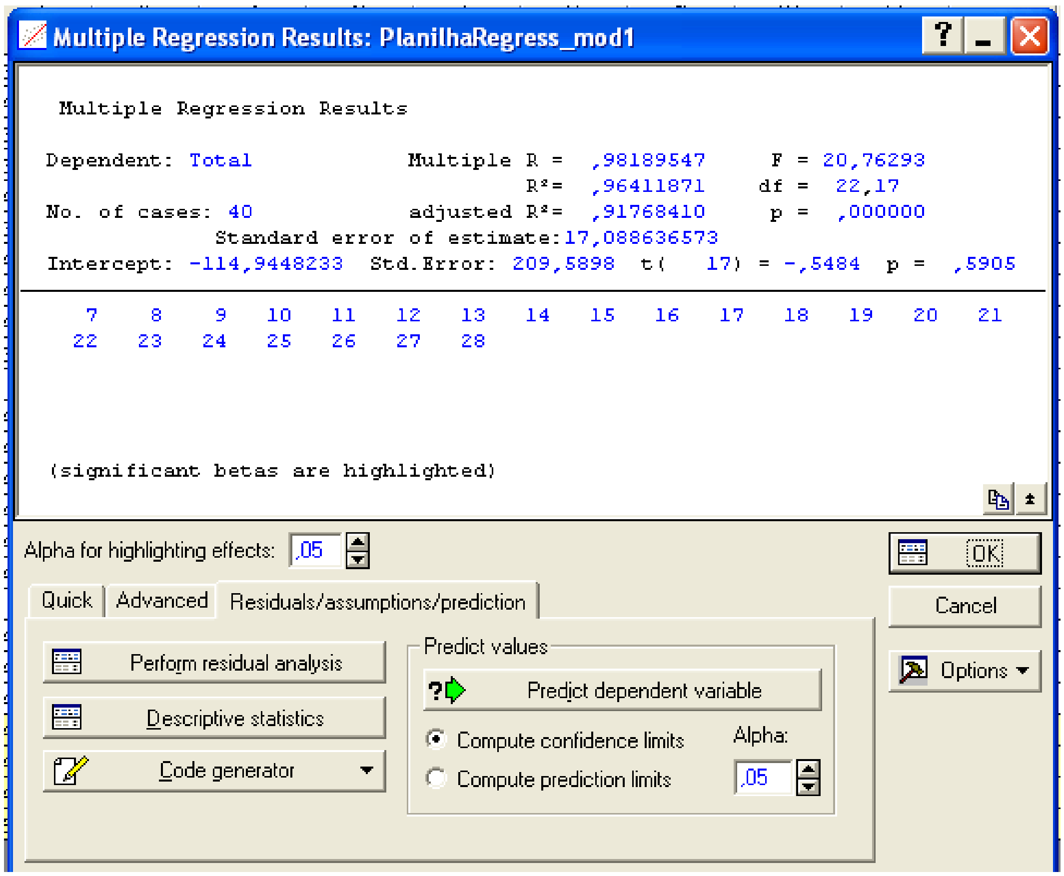


Figure 5.5 Regression Summary and Significant Variables – First Model

Additionally, analyzing again Table 5.5, it is possible to notice very high p-levels for the variables. Therefore, it is possible to conclude that the significance of each variable is low. Confirming this conclusion, the t value, another index which is directly related to the p-level, does not achieve satisfactory indexes. Excepting the variable (t-12), all the others had substandard results not achieving at least 2.00 (see Table 5.5).

Figure 5.6 shows a good correlation of the predicted values versus the observed dependent variable. The points are considerably aligned with the ideal relation of observed and predicted values pointing for good model accuracy.

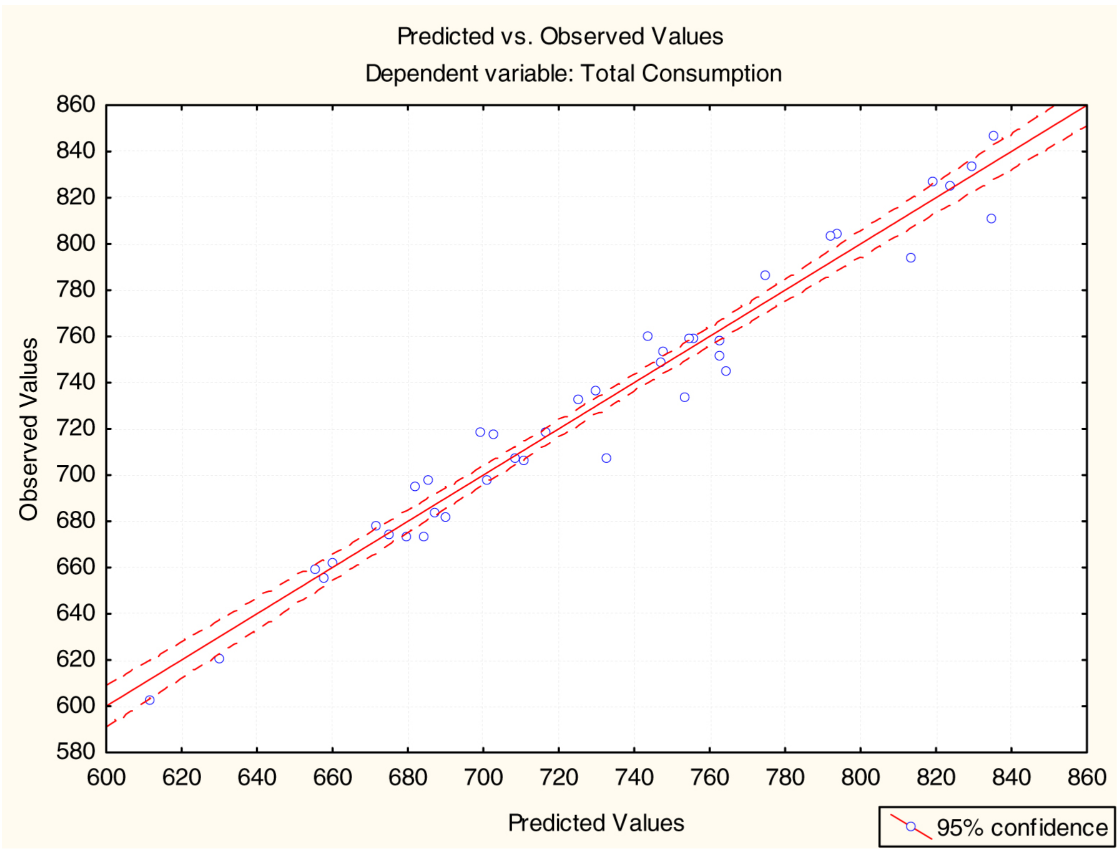


Figure 5.6 Predicted vs. Observed Values – First Model

Additionally, the first regression presented also a good response concerning its residuals. Figure 5.7 shows the analysis of the residuals versus the dependent variable. The picture shows a cloud of points that does not reveal any systematic behavior, which is another good evidence of model accuracy.

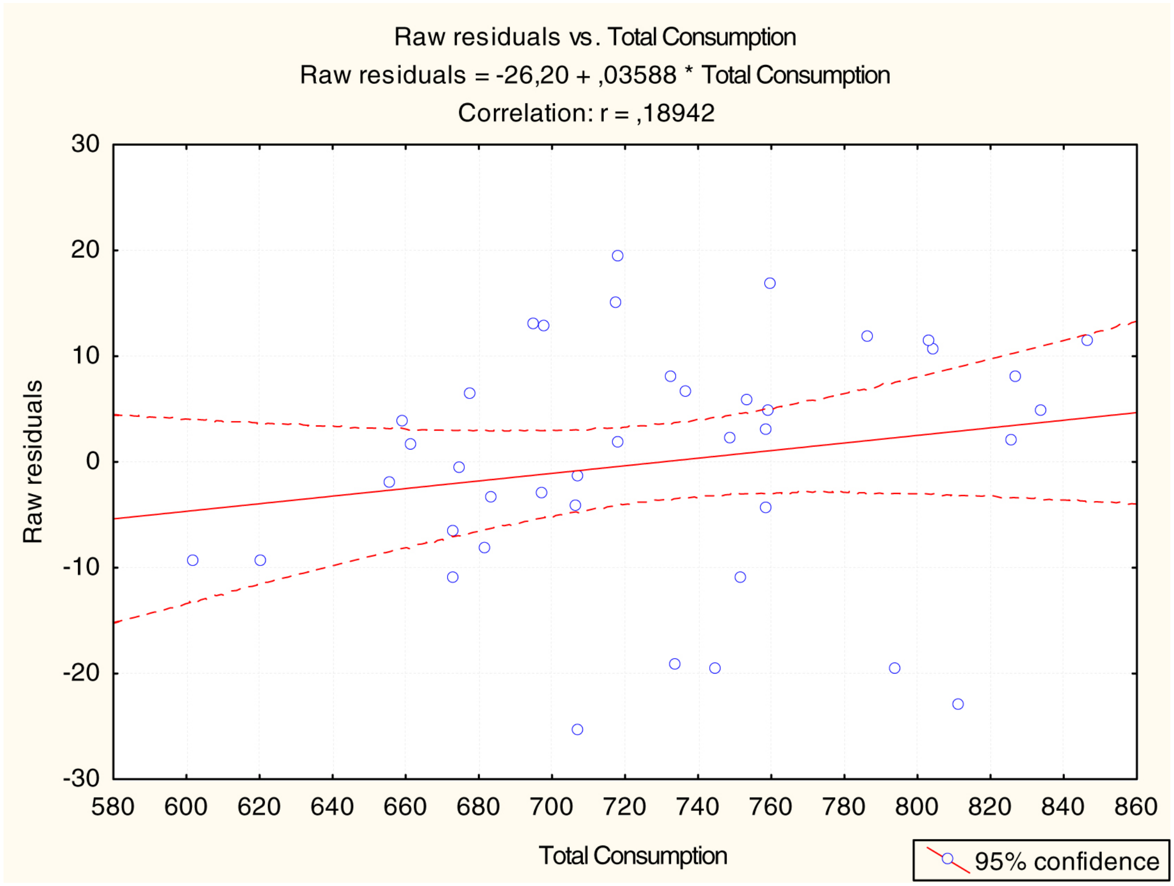


Figure 5.7 Raw Residuals vs. Dependent Variable – First Model

Figure 5.8 shows the normal probability plot of residuals, presenting a good alignment of points indicating good model precision.

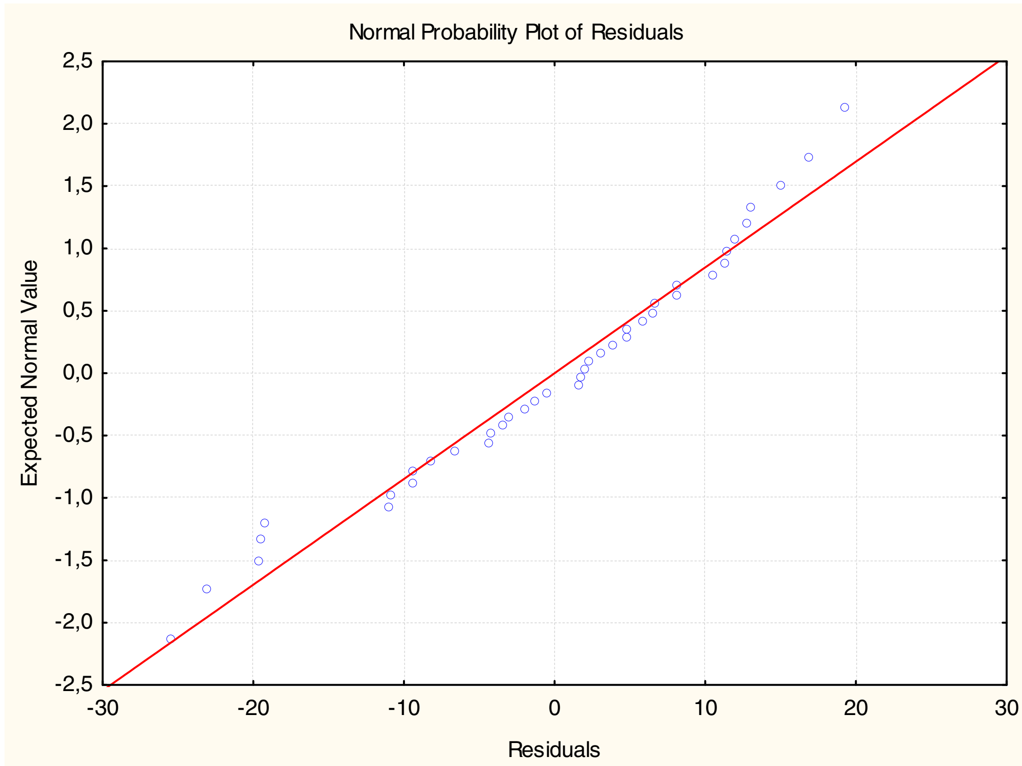


Figure 5.8 Normal Probability Plot of Residuals – First Model

Also, the distribution of raw residuals shows a close behavior to the expected one, which again points for the good precision of the model.

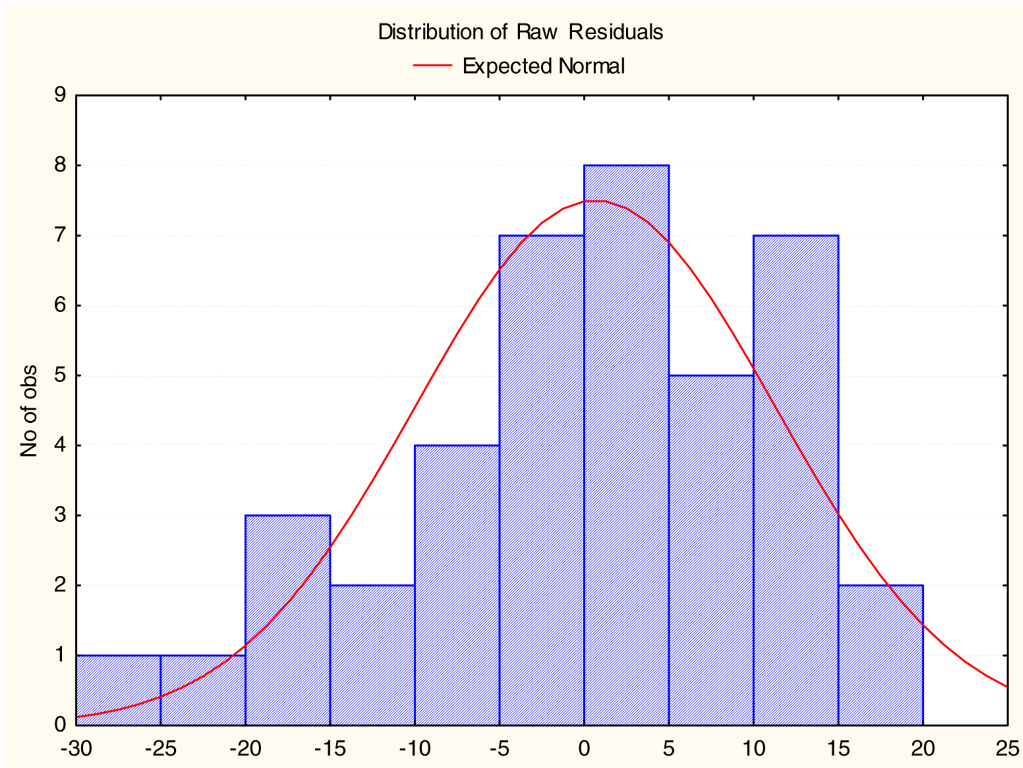


Figure 5.9 Distribution of Raw Residuals – First Model

In sum, the model presents very good indicators for accuracy as a global set, but poor indicators regarding the statistical significance of each variable. So, the program shows that there are too many predictors in the model, diluting the significance of each variable. Consequently, the model accuracy reached good levels, but the bias is not satisfactory.

5.3.5. The Second Regression Model

Searching for a model that could provide good model accuracy and reasonable bias, a second model was developed. The main intention was to identify and select significant variables to promote better cause-effect relationships.

Therefore, the first step to promote this selection was making a correlation analysis together with some variable transformations. This process evaluated the correlation between each variable and the dependent variable (demand). Additionally, transformations changed all the series to their power of two, to their natural log, and their inverse. The correlation between each of the transformed series and the dependent variable was given as well. This process permitted the fact of discharging several variables: *CDD*(x_4), *Received Days (dias faturados*) (x_8), *(t-12)* (x_{16}),, *IGPM*(x_{12})*, IGP-DI* (x_{13})*, SELIC – Interest Rate %* (x_{14})*, SELIC (year) – Yearly Interest Rate %* (x_{15})*, Dollar Rate (Buying Price)* (x_{16})*, Industrial Production – Edition and Impression* (x_{22})*, Industrial Production –Food*($x_{22)}$ were discharged for presenting a correlation coefficient lower than 0.40, as can be seen in tables A-3 to A-10 (Appendix). The variable *Industrial Production (Paulista)* (x_5) was also discharged even having a correlation coefficient equal to 0.69. The reason for that is that being similar to other variables with better correlation coefficients, *Industrial Production (Paulista)* (x_5) could insert in the model redundant information (see table A-9).

The second model was the one summarized in Figure 5.10 and Table 5.6.

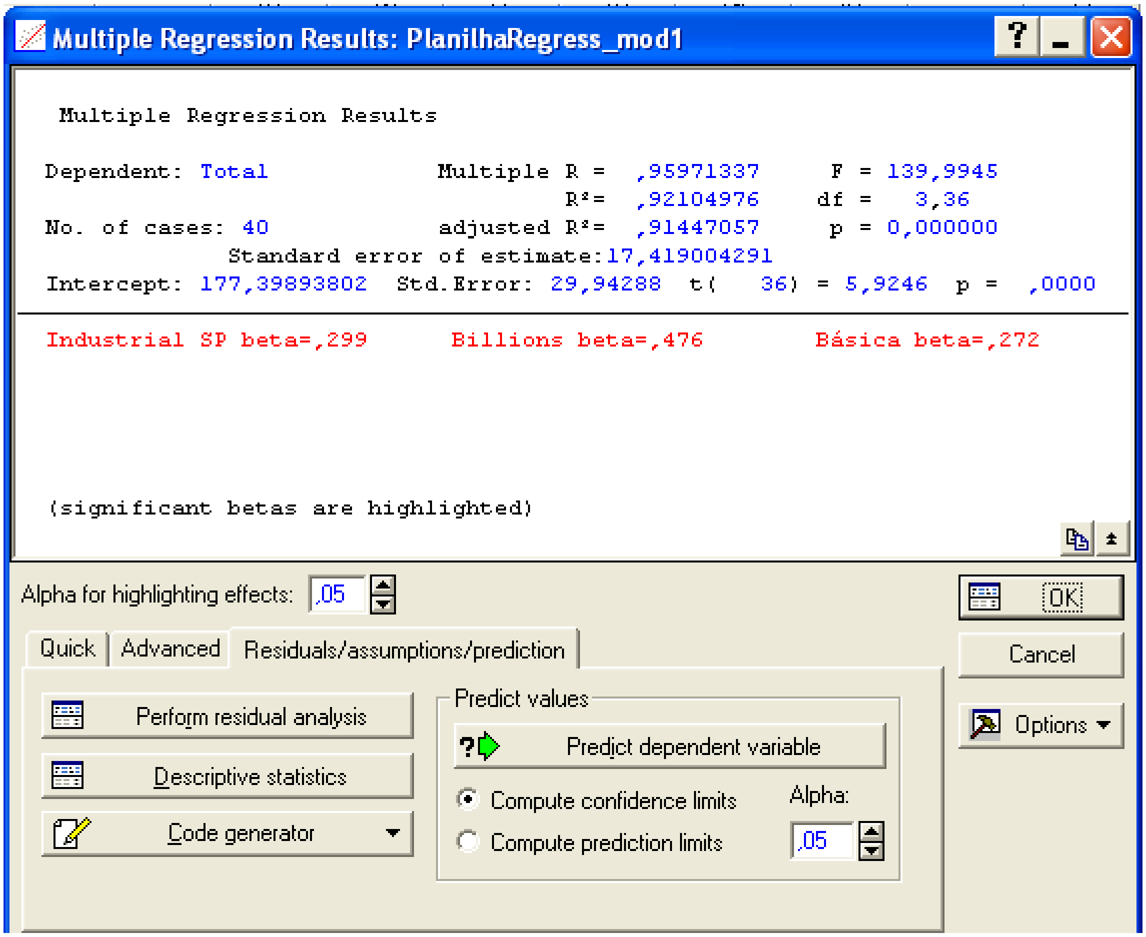


Figure 5.10 Regression Results and Significant Variables – Second Model

Table 5.6 Second Model - Summary

N=40	Regression Summary for Dependent Variable: Total (PlanilhaRe R= ,95971337 R²= ,92104976 Adjusted R²= ,91447057 F(3,36)=139,99 p<0,0000 Std.Error of estimate: 17,419					
	Beta	Std.Err. of Beta	B	Std.Err. of B	t(36)	p-level
Intercept			177,3989	29,94288	5,924579	0,000001
Industrial SP	0,299203	0,092028	1,8337	0,56401	3,251233	0,002497
Billions	0,475813	0,072550	1,6418	0,25034	6,558391	0,000000
Basic	0,272096	0,104203	8,4767	3,24626	2,611216	0,013072

As observed in Figure 5.10 and Table 5.6, the second model presents elevated numbers for the R^2 value and the adjusted R^2 value. They are slightly lower than the values found in the first model, but equally acceptable. The F(3,36) =139,99 is higher then Fo = 8.63 representing a good accuracy index also (see Table A-2). Finally, the p index makes another good indicator, being lower than 0.000000. Consequently, the second model presents a good level of accuracy.

A significant difference between the first and the second model can be seen in Table 5.6. Now, there are three significant variables highlighted in red, as summarized in Table 5.7:

Table 5.7 Significant Variables

x_7	*Industrial Production (Sao Paulo)*
x11	*GDP Billions*
x19	*Industrial Production – Basic Metallurgy*

Other indicators show that the second model presents significant variables also. Examining Table 5.6, it is possible to see that all the t values are all above 2.00, what is considered good. Additionally, the p-level is also very low for all the explicative variables.

The model also shows good consistency when comparing the predicted versus the observed values, as shown in Figure 5.11.

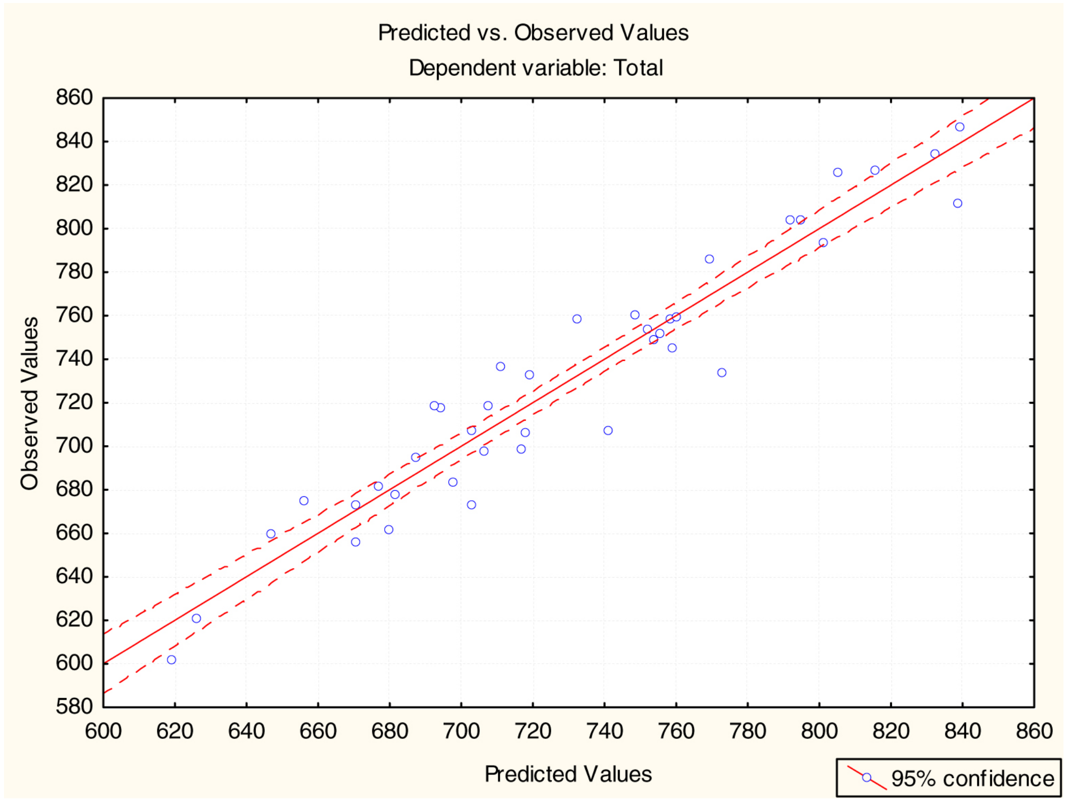


Figure 5.11 Predicted vs. Observed Values – Second Model

The model presented good residual analysis as well. Figure 5.12 shows the relation between raw residuals and the explanatory variable.

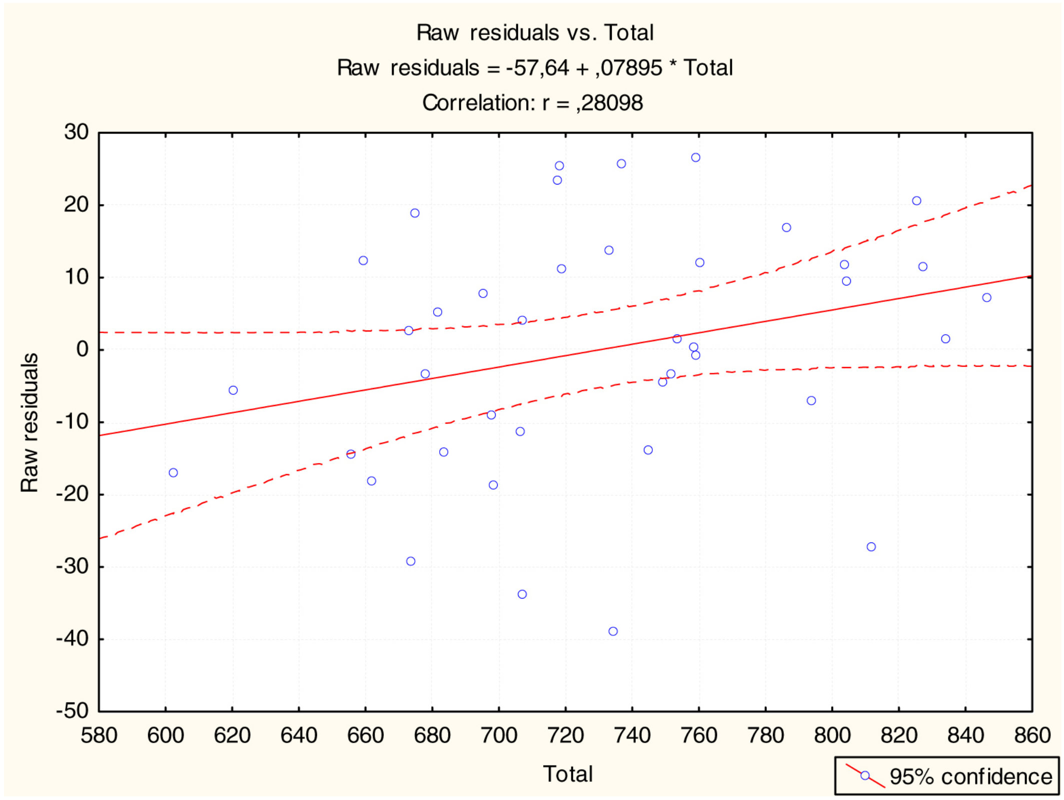


Figure 5.12 Raw Residual vs. Total Raw Residuals – Second Model

The distribution of raw material resembles a normal curve in a satisfactory way, as seen in Figure 5.13.

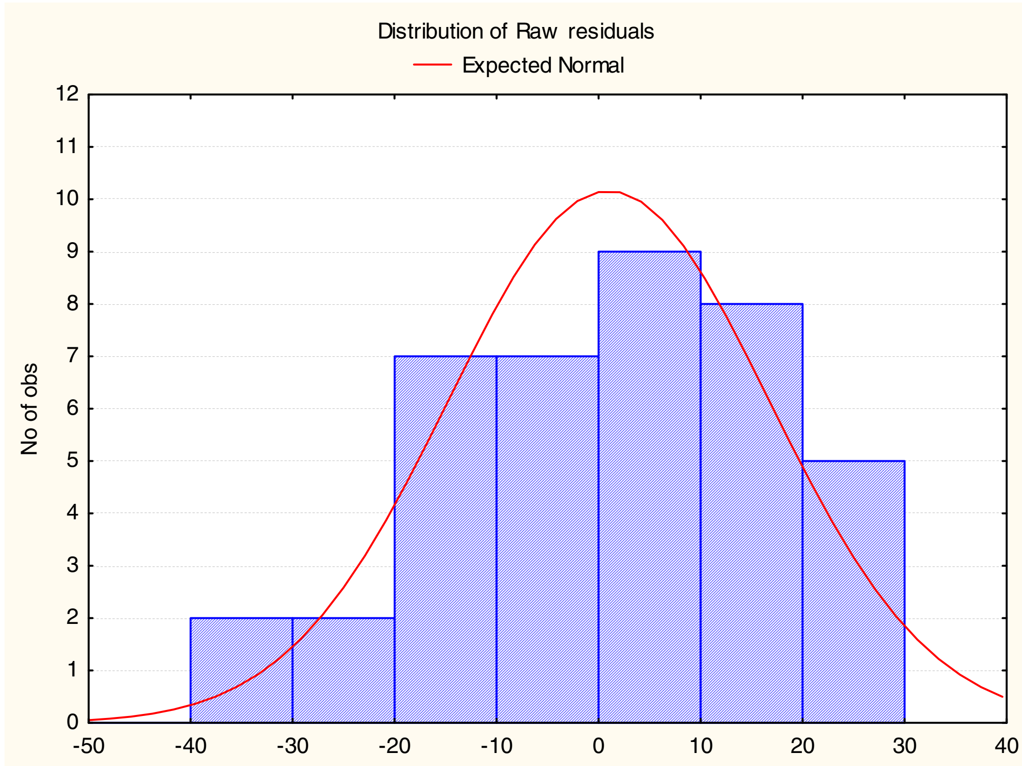


Figure 5.13 Distribution of Raw Materials – Second Model

The normal probability plot of residuals graphic (Figure 5.14) shows a good alignment.

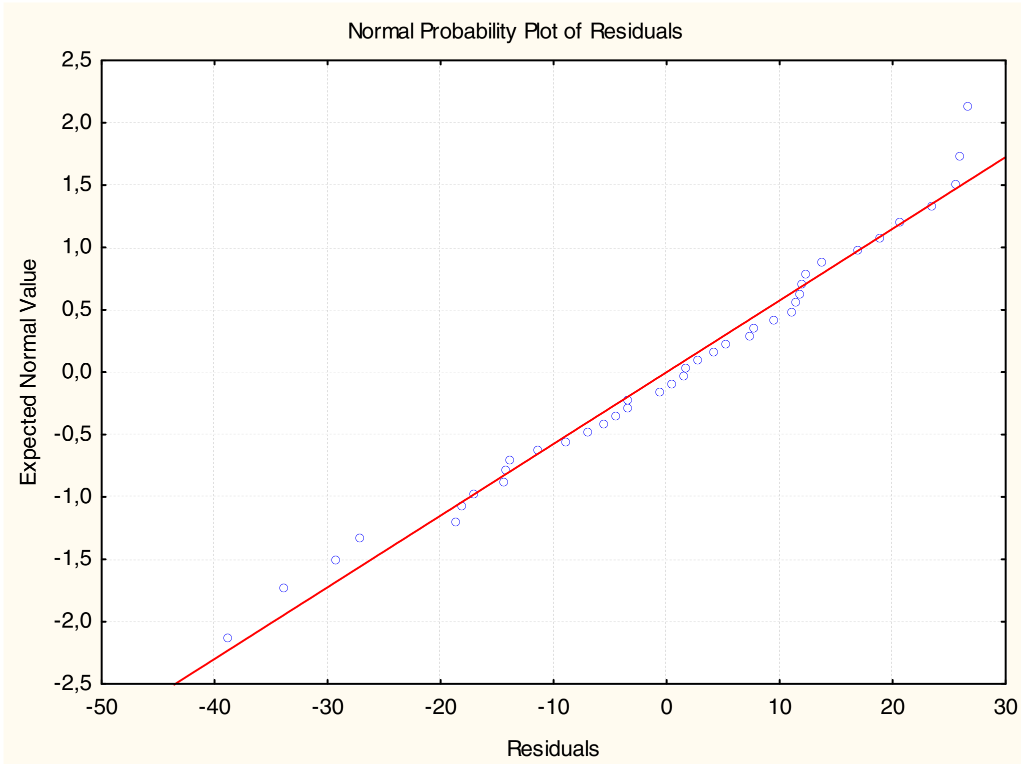
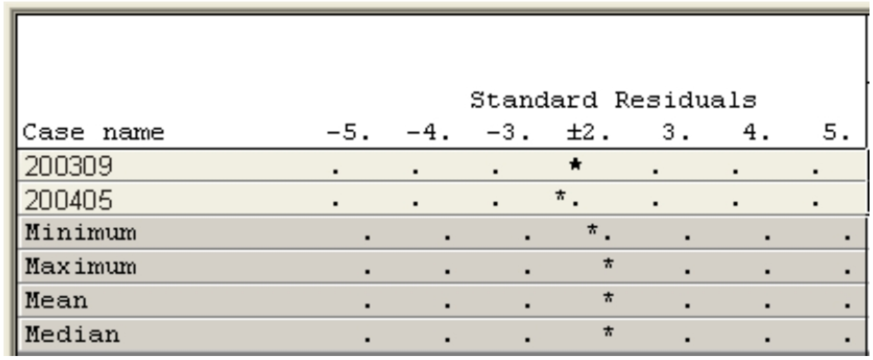


Figure 5.14 Normal Probability Plots of Residuals – Second Model

So, the second model shows not only good accuracy, but also good indicators concerning the statistical significance of each variable. However, the model shows two outliers that disturb the results as shown in Figure 5.15.



Case name	-5.	-4.	-3.	±2.	3.	4.	5.
200309	.	.	.	*	.	.	.
200405	.	.	.	*.	.	.	.
Minimum	.	.	.	*.	.	.	.
Maximum	.	.	.	*	.	.	.
Mean	.	.	.	*	.	.	.
Median	.	.	.	*	.	.	.

Figure 5.15 Outliers

Therefore, it is possible to conclude that eliminating these two outliers, a model with better accuracy is feasible.

5.3.6. The Final Regression Model

The final model was the one which finally achieved high accuracy and high prediction bias associated to high level of variable significance. The data from September 2003 and May 2004 were eliminated, and the results improved considerably. Tables 5.8 and Figure 5.16 summarize the results.

Table 5.8 Summary of Final Regression Model

	Regression Summary for Dependent Variable: Total Consumption R= ,96963215 R²= ,94018651 Adjusted R²= ,93420516 F(3,30)=157,19 p<,00000 Std.Error of estimate: 15,534					
N=34	Beta	Std.Err. of Beta	B	Std.Err. of B	t(30)	p-level
Intercept			171,8107	27,43431	6,262620	0,000001
Industrial SP	0,363320	0,091296	2,1497	0,54018	3,979584	0,000404
PIB Billions	0,458664	0,068088	1,6123	0,23934	6,736370	0,000000
Basic Metalurgy	0,234589	0,097938	7,1923	3,00272	2,395279	0,023053

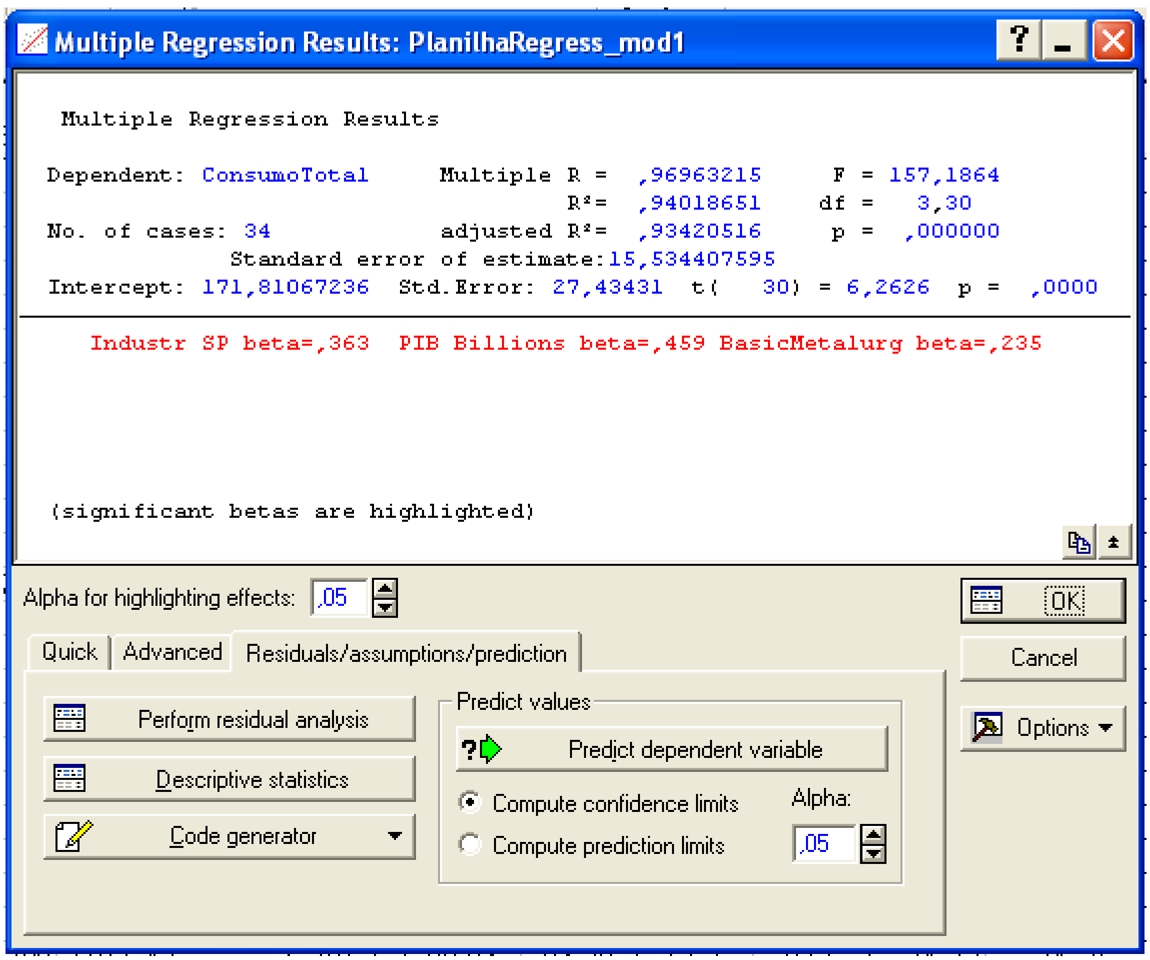


Figure 5.16 Summaries of Final Regression Model and Significant Variables

R^2 was improved to 0.94018651, and the Adjusted R^2 was improved to 0.93420516 and the p value is < lower than 0.00000. The F (3,3o) = 157.19 is higher than Fo = 8.62 (see Table A-7 – Appendix). The model demonstrates elevated variable significance for the three explanatory variables. The t value and the p-level confirm the variable significance for all of them.

The model shows good results when comparing the predicted versus the observed values, as shown in Figure 5.17.

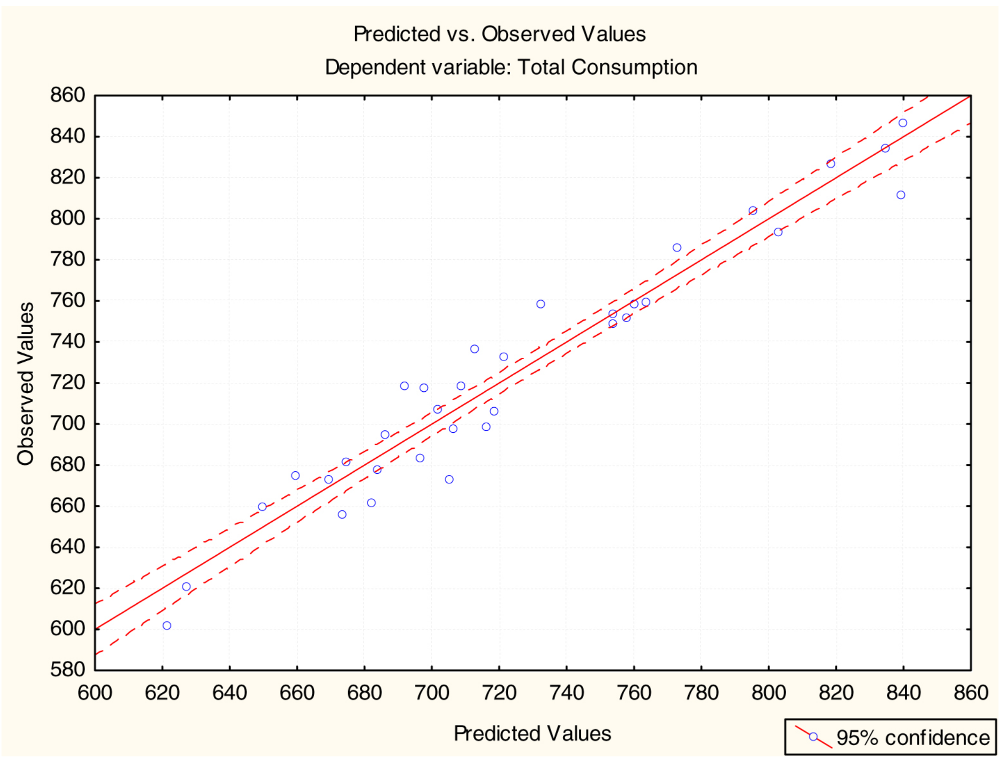


Figure 5.17 Predicted vs. Observed Variables – Final Model

The model presented excellent residual analysis as well. Figure 5.18 shows the relation between raw residuals and the explanatory variable. The picture illustrates a cloud of points that does not reveal any systematic behavior.

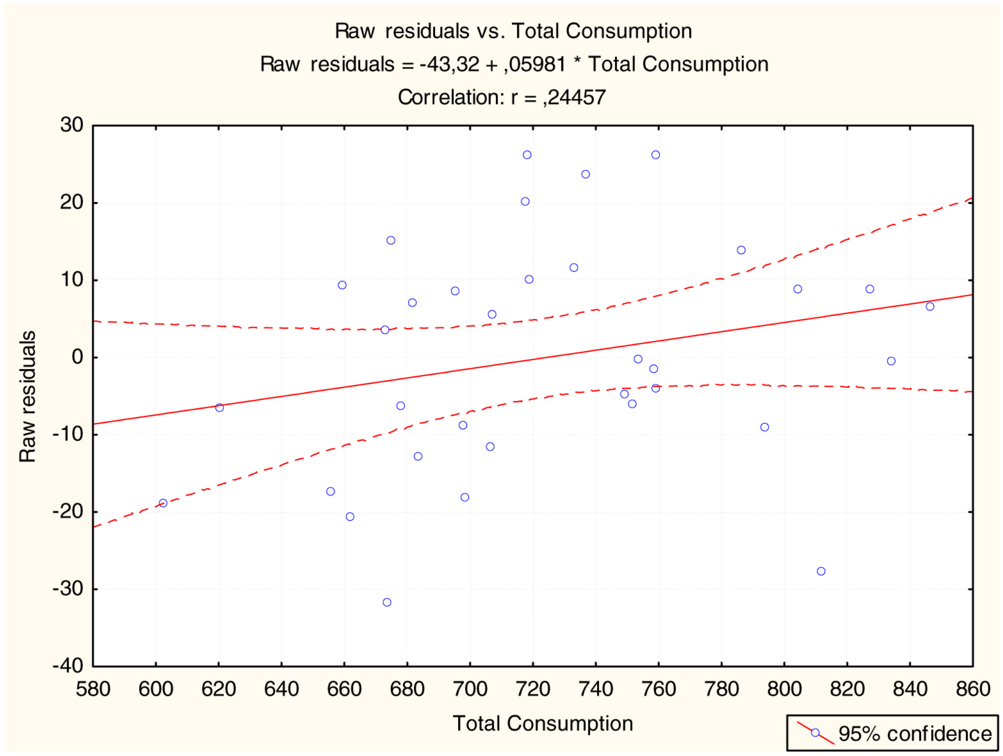


Figure 5.18 Raw Residual vs. Total Consumption – Final Model

Again, the normal probability plot of residuals graphic (Figure 5.19) illustrates a fine alignment. Visually comparing to the other two plots, it is possible to say that it is even slightly better.

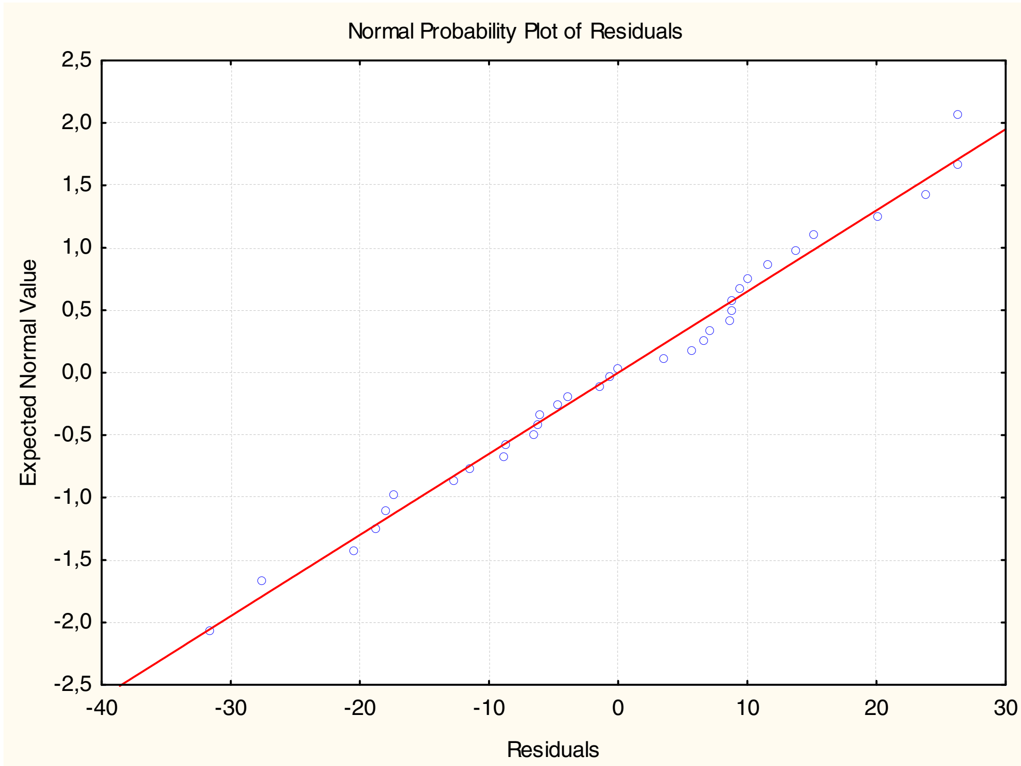


Figure 5.19 Normal Probability Plot of Results – Final Model

Finally it is interesting to observe that this model provided visually the best behavior of distribution of raw residuals, as shown in Figure 5.20.

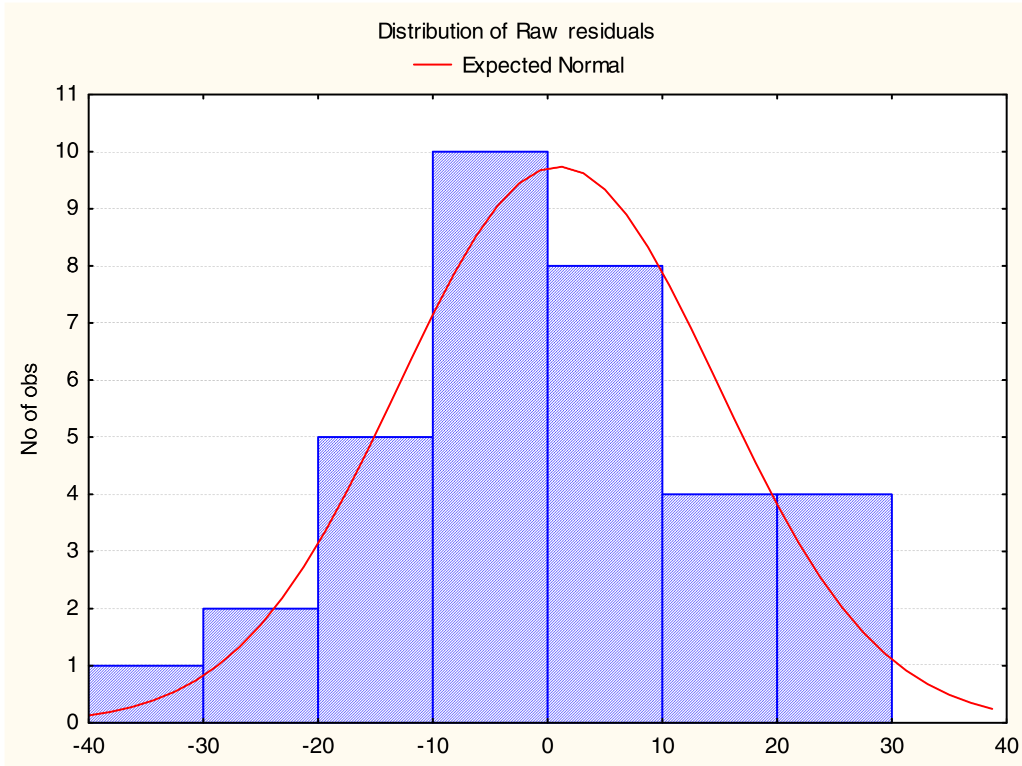


Figure 5.20 Distribution of Raw Residuals – Final Model

5.4. Test of the Predictive Performance of the Different Models (Validation Period)

In order to evaluate the models, the error is calculated following the procedure:

Error1 = (Forecasted Demand – Observed Demand)/ Observed Demand

Error2 = same equation from Error1, but it does not consider data from December 2005 due to possible error in the approximation method (the observed value was not available, so it was obtained from a growth index calculation).

5.4.1. The First Model

Table 5.9 First Model Errors

Forecasted			Observed
Ind Demand	Error	Year/month	Ind Demand
1391,349116	86.79%	200501	744,876
1353,065633	77.99%	200502	760,202
1389,340151	72.89%	200503	803,607
1436,846338	74.04%	200504	825,605
1326,730406	65.29%	200505	802,645
1347,295006	65.66%	200506	813,297
1358,105951	63.14%	200507	832,494
1394,220228	68.10%	200508	829,39
1412,666433	67.46%	200509	843,592
1412,021777	64.48%	200510	858,487
1400,733985	66.86%	200511	839,47
1244,25905	60.54%	200512	775,027
Sum =	833.23%	Sum =	9728,692
Sum2=	772.69%		
Sum			
16466,63407	69.26%	Error1	
15222,37502	56.47%	Error2	

The first model does not present good results. Error1 is equal to 69.6% which is very high. Moreover, the sum of the monthly error is very high, showing that the model's error is systematically positive.

5.4.2. Second Model

Table 5.10 Second Model Errors

Second Model						
	Observed	Production	GDP	Basic	Forecasted	
	Ind Demand	Industrial SP	Billions	Metallurgy	Ind Demand	Error
200501	744,876	103,14	146,074	17,97363	758,7080809	1.86%
200502	760,202	97,77	146,074	17,90098	748,2453177	–1.57%
200503	803,607	112,34	146,074	19,88026	791,7400607	–1.48%
200504	825,605	110,49	160,055	19,14387	805,0595657	–2.49%
200505	802,645	117,04	160,055	19,28949	818,3047072	1.95%
200506	813,297	118,88	160,055	16,59044	798,799677	–1.78%
200507	832,494	116,67	165,7853	18,95464	824,1958019	–1.00%
200508	829,39	126,06	165,7853	19,2149	843,6204227	1.72%
200509	843,592	122,19	165,7853	20,10776	844,0925548	0.06%
200510	858,487	121,4	173,9517	19,50006	850,900078	–0.88%
200511	839,47	121,19	173,9517	19,39931	849,6610202	1.21%
200512	775,027	112,7	173,9517	20,04354	839,5537966	8.33%
					Sum =	5.92%
					Sum2=	–2.40%
	Sum				Sum	Error
	9728,692				9772,881083	0.45%
	8983,816				8933,327287	–0.56%

The second model shows satisfactory results. The Error1 is 0.45%, which is very good. Another error value was also calculated considering the numbers from December 2005 are not real but obtained from a growth index calculation, and could negatively influence the results. Therefore, Error2 is obtained discharging the values from December 2005, and is equal to 0.56%, which is equally very good. Sum2 (which discharges the values from December 2005) shows a better result, closer to zero.

5.4.3. The Final Model

Table 5.11 Final Model Errors

	Observed	Production	GDP	Basic	Forecasted	
	Ind. Demand	Industrial SP	Billions	Metallurgy	Ind Demand	Error
200501	744,876	103,14	146,074	17,97	758,3176075	1.80%
200502	760,202	97,77	146,074	17,90	746,2512301	–1.84%
200503	803,607	112,34	146,074	19,88	791,8079103	–1.47%
200504	825,605	110,49	160,055	19,14	805,0761949	–2.49%
200505	802,645	117,04	160,055	19,29	820,2040977	2.19%
200506	813,297	118,88	160,055	16,59	804,7471674	–1.05%
200507	832,494	116,67	165,78533	18,95	826,2393202	–0.75%
200508	829,39	126,06	165,78533	19,21	848,2968982	2.28%
200509	843,592	122,19	165,78533	20,11	846,3993141	0.33%
200510	858,487	121,4	173,95167	19,50	853,4968278	–0.58%
200511	839,47	121,19	173,95167	19,40	852,3208062	1.53%
200512	775,027	112,7	173,95167	20,04	838,7033019	8.22%
					Sum =	8.18%
					Sum2=	–0.04%
	Sum				Sum	Error
	9728,692				9791,860676	0.65%
	8983,816				8953,157374	–0.34%

The final model shows very good accuracy, especially when considering Error2 and Sum of Error2. The errors do not show any systematic behavior. Observing the last column, it is possible to see that all errors are low, but the error from December 2005. With out considering this month, the Sum2 is nearly equal to 0.00.

Chapter 6

Conclusions

The first important conclusion comes from the monopolistic attribute of the electricity industry in the past. In Brazil, where the companies were government properties, and also in the U.S., electricity utilities were based in vertical organizations and monopolistic markets enclosed by concession areas. This monopolistic aspect brought to the industry a deficient strategic vision. Formerly, there was a poor interface between companies and consumers that signifies a lack in customer relationship management procedures. According to Chopra and Meindl, the concept of supply chain is based on the involvement of all parties including suppliers, manufacturer, transporters, warehousers, retailers, and consumers themselves. The final intention is to maximize information exchange, integrate processes and tasks to fulfill all consumers' needs. Under a supply chain perspective, because of the past history, electrical utilities still have a low capacity of obtaining consumer's information and consequently, a low capacity of developing other important tools such as precise demand forecasts which are vital today if compared to other sectors of the industry. In this way, improving marketing and consumer relationship is a current goal to advance the utilities' foundations on strategic planning. Additionally, as the number of free consumers grows (as shown in Figure 1.3), in Brazil, the importance of developing efficient tools to better serve and captivate your customer becomes greater. The difficulty of acquiring data related to CPFL consumers attests to this idea. The historical series were restricted to the period from January 2001 to December 2005, and a larger interval would provide even more consistency.

Another important conclusion is that the behavior of a big electricity utility, such as CPFL's, can be well explained by the large picture of the economy. This can be elucidated by the fact that CPFL operates in the state of Sao Paulo which is the most industrialized state of the country and produces a big percentage of the national economy's outcome. As observed in the final model, the Brazilian GDP showed to be a very consistent explanatory variable. Additionally, it is interesting to observe that the industrial production of the whole state of Sao Paulo showed a better relationship with CPFL's Paulista electricity demand than a local industrial production (*Industrial Production (Paulista)* ($\mathbf{x_5}$)).

Being the foundation for many other industry segments, the basic metallurgy sector was selected in the final model as well. Therefore, the presupposition that basic metallurgy impacted many other sectors of the industry and consequently the whole economy and the electricity demand was validated.

Furthermore, the first model based on a big set of variables reveals fascinating conclusions. Initially, there is a technical problem: the model presents very good indicators for accuracy as a global set, but poor indicators regarding the statistical significance of each variable. This fact results in good model accuracy, but the bias is not acceptable. The explanation for this problem is that too many predictors into the model dilute the significance of each variable. As seen in Figure 4.6, none of the variables are highlighted in red color, which means they are significant. Besides, the first approach demonstrated that models with many variables expose interpretation difficulties. It is hard to find cause-effect relationships between independent explanatory variables and the dependent explanatory variable. A good example would be to study the effect of the SELIC interest rate in the observed demand: As the effect of SELIC interest rate is not punctual, but accumulative, the relationship of this variable with the industrial observed demand does not show a fast and direct correlation.

One more interesting conclusion comes from the explanatory variable transformation process. In order to find new relations with the independent variable, the dependent variables passed through a transformation process shown by Tables A-3 to A-10 (Appendix). Numbers were changed to their power of two, to their natural log, and their inverse. However, none of the variables presented better correlation after the transformation. This shows that the best association of variables was given by a direct relationship.

Also, analyzing again the final model, it is possible to see that the result of the test suffered prejudice from a number contained in the basic metallurgy industrial physical production set. The value of 2005 was not available. Then, this number was obtained from a growth index calculation. Eliminating this number provides very good results.

Additionally, the final model proved that macroeconomic variables and industrial production data represent very good data to predict accurate electricity demand forecasting models related to industrial consumer segment for an electric utility. This model achieved very good results obtaining the Error2 equal to -0.34% and the sum of Errors2 equal to -0.04% showing no systematic behavior.

As Brazil is a developing nation, the economic growth indexes are high and trend extrapolations methods has limited prediction capacity since it is based only the historical behavior, not capturing effects of economy expansions and recessions that are common events in this category of countries. So, the method used in this work proved to be a much more consistent and reliable one.

As a result, this work signifies a considerable benefit to the utility industry for making possible more accurately predicting electricity sales and consequently being prepared for better planning future investments as well as managing and controlling the facilities with precision. Underestimates signify not properly investing in growth and losing important business opportunities. Overestimates signify unnecessary large investments that can financially damage the company. In addition, unnecessary large investments signify a cost for consumers in the form of higher tariffs and to the society which will see energy prices going up. As a consequence, inflation can be a final result since all products are dependent on energy to be produced. Accurate forecasts can prevent these possible societal costs.

Furthermore, accurate forecasts signify a benefit to society because they prevent unnecessary environmental impacts. Investing unnecessarily in new plants signifies harming the environment, remembering that although hydroelectric plants do not pollute, their lakes occupy large environmental areas. Also, thermoelectric plants can better plan their demand for fuel, promoting conservation of energy which is such an important issue today.

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Appendices

Appendix A: Supplementary Tables

Table A-1 Spreadsheet Used in Regression Models

Explanatory Variables									
	CPFL Paul.		Physical Production				Physical Production		CPFL
	Ind.Demand	High	Medium	Low	CDD	Industry	Industry	Industry	Received Days
Year/month	Total (GWh)	Intensity	Intensity	Intensity	CDD	Paulista	Brazil	Sao Paulo	
200201	602,256	93,7	91,24	89,25	86,0	87,9	90,75	88,25	30
200202	620,478	90,0	88,13	85,93	54,1	86,9	87,85	88,63	30
200203	659,317	98,3	94,96	97,79	115,4	94,0	97,04	97,14	30
200204	655,85	98,4	100,1	101,42	80,3	99,6	100,11	99,39	30
200205	677,784	100,9	98,2	102,65	19,6	101,4	100,48	101,95	31
200206	674,702	98,1	92,7	99,03	2,6	98,9	96,8	96,97	31
200207	673,37	103,6	104,95	105,58	0,5	107,0	104,53	105,17	31
200208	717,662	104,3	106,45	105,39	28,0	109,2	105,34	104,6	30
200209	718,564	102,3	105,39	103,16	25,9	108,3	103,82	104,06	31
200210	751,821	109,3	115,13	112,96	135,3	115,5	113,18	115,66	31
200211	758,752	104,5	108,47	105,03	70,0	105,2	106,3	105,91	31
200212	695,043	96,6	94,29	91,81	98,3	90,0	93,75	92,21	31
200301	681,752	99,9	92,97	88,55	83,4	90,7	92,22	89,47	31
200302	672,994	94,9	90,06	87,31	117,8	88,8	90,26	89,73	29
200303	718,241	102,4	94,26	95,36	65,8	94,5	96,04	95,45	30
200304	683,595	98,5	94,68	95,54	27,1	91,3	95,38	92,47	29
200305	698,232	102,9	94,66	100,78	1,8	98,7	99,26	98,58	31
200306	661,718	98,4	89,97	96,65	5,4	96,1	95,02	94,22	30
200307	706,695	103,0	100,62	102,67	0,0	102,5	101,9	98,89	31
200308	732,987	104,2	100,75	102,67	0,5	106,3	102,44	102,33	31
200309	707,191	105,8	105,32	110,09	28,3	110,0	107,97	107,62	30
200310	786,354	110,5	110,81	116,01	55,6	114,6	113,92	114,55	31
200311	758,486	104,6	104,16	108,57	50,2	104,9	107,92	109,43	30
200312	736,601	98,4	94,75	99,2	80,9	87,8	98,23	97,73	30
200401	697,635	101,3	93,24	94,73	61,2	92,1	95,73	95,3	32
200402	707,193	98,2	90,85	90,64	56,7	90,9	92,09	92,29	29
200403	753,673	111,1	105,47	109,53	43,5	104,3	108,9	110,02	31
200404	749,031	106,0	96,98	104,02	33,3	98,6	102,59	103,17	31
200405	734,022	111,6	103,06	108,53	1,1	106,9	108,03	110,04	30
200406	759,338	111,4	103,4	108,07	0,0	110,1	107,86	109,98	31

Appendix A: (Continued)

Table A-1 (Continued)

	CPFL Paul.		Physical Production				Physical Production		CPFL
	Ind.Demand	High	Medium	Low	CDD	Industry	Industry	Industry	Received Days
Year/month	Total (GWh)	Intensity	Intensity	Intensity	CDD	Paulista	Brazil	Sao Paulo	
200407	793,983	114,8	110,73	113,31	0,0	116,8	112,58	115,49	30
200408	827,001	118,2	112,47	115,68	4,5	121,4	116,11	120,33	30
200409	834,002	115,6	111,58	117,71	71,4	121,8	116,05	124,01	31
200410	846,6	117,2	113,05	119,63	20,5	120,5	117,62	120,57	30
200411	811,396	112,6	112,23	118,7	45,0	114,7	116,29	120,1	30
200412	804,197	104,7	102,14	109,83	62,3	97,5	106,41	109,36	30
200501	744,876	105,3	96,61	101,9	76,3	96,1	101,45	103,14	32
200502	760,202	100,9	94,05	93,61	75,8	93,5	95,89	97,77	28
200503	803,607	111,6	107,84	111,45	82,0	106,1	110,81	112,34	29
200504	825,605	110,6	103,12	111,38	75,3	105,3	109,12	110,49	32
200505	802,645	112,5	103,68	120,78	8,9	110,6	114,06	117,04	29
200506	813,297	112,6	104,02	121,25	0,0	114,9	114,77	118,88	31
200507	832,494	111,9	105,07	119,1	0,4	119,3	113,32	116,67	31
200508	829,39	116,7	112,06	126,23	8,6	127,2	120,39	126,06	31
200509	843,592	113,6	108,21	120,53	14,4	126,4	115,99	122,19	31
200510	858,487	115,1	110,17	123,37	86,6	125,3	117,94	121,4	31
200511	839,47	113,1	110,08	121,95	56,4	119,3	117,4	121,19	31
200512	775,027	105,2	100,92	114,39	61,0	100,4	109,34	112,7	31

Appendix A: (Continued)

Table A-1 (Continued)

Explanatory Variables							
	CPFL	CPFL	Brazil	Brazil	Brazil	Brazil	Brazil
	Demand	Demand	GDP (Real)	Inflation	Inflation	Interest R	Interest R
Year/month	(t-1)(GWh)	(t-12)(GWh)	Billions	IGPM	IGP-DI	SELIC %	SELIC % (year)
200201	603,368	658,556	100,22	0,36	0,19	1,6	19,05
200202	602,256	746,657	100,22	0,06	0,18	1,25	19,05
200203	620,478	677,868	100,22	0,09	0,11	1,38	18,8
200204	659,317	724,869	110,22	0,56	0,7	1,28	18,45
200205	655,850	699,721	110,22	0,83	1,11	1,62	18,35
200206	677,784	851,862	110,22	1,54	1,74	1,26	18,07
200207	674,702	591,055	114,51	1,95	2,05	1,35	18,4
200208	673,370	633,528	114,51	2,32	2,36	1,64	17,86
200209	717,662	615,879	114,51	2,4	2,64	1,31	17,87
200210	718,564	622,722	123,73	3,87	4,21	0,53	20,9
200211	751,821	644,863	123,73	5,19	5,84	1,44	20,9
200212	758,752	603,368	123,73	3,75	2,7	1,58	21,9
200301	695,043	602,256	119,6	2,33	2,17	2,05	24,9
200302	681,752	620,478	119,6	2,28	1,59	1,81	25,36
200303	672,994	659,317	119,6	1,53	1,66	1,68	26,3
200304	718,241	655,850	128,13	0,92	0,41	2,16	26,32
200305	683,595	677,784	128,13	-0,26	-0,67	1,78	26,32
200306	698,232	674,702	128,13	-1	-0,7	1,87	26,27
200307	661,718	673,370	132,24	-0,42	-0,2	2,21	25,74
200308	706,695	717,662	132,24	0,38	0,62	1,74	24,32
200309	732,987	718,564	132,24	1,18	1,05	1,58	21,84
200310	707,191	751,821	138,75	0,38	0,44	1,81	19,84
200311	786,354	758,752	138,75	0,49	0,48	1,38	18,84
200312	758,486	695,043	138,75	0,61	0,6	1,28	17,32
200401	736,601	681,752	131,89	0,88	0,8	1,39	16,32
200402	697,635	672,994	131,89	0,69	1,08	1,21	16,3
200403	707,193	718,241	131,89	1,13	0,93	1,08	16,28
200404	753,673	683,595	145,18	1,21	1,15	1,13	16,09
200405	749,031	698,232	145,18	1,31	1,46	1,41	15,8
200406	734,022	661,718	145,18	1,38	1,29	1,11	15,79
200407	759,338	706,695	152,35	1,31	1,14	1,46	15,79
200408	793,983	732,987	152,35	1,22	1,31	1,17	15,83
200409	827,001	707,191	152,35	0,69	0,48	1,12	15,9
200410	834,002	786,354	159,45	0,39	0,53	1,44	16,23
200411	846,600	758,486	159,45	0,82	0,82	1,11	16,71
200412	811,396	736,601	159,45	0,74	0,52	1,27	17,23

Appendix A: (Continued)

Table A-1 (Continued)

Explanatory Variables							
	CPFL	CPFL	Brazil	Brazil	Brazil	Brazil	Brazil
	Demand	Demand	GDP (Real)	Inflation	Inflation	Interest R	Interest R
Year/month	(t-1)(GWh)	(t-12)(GWh)	Billions	IGPM	IGP-DI	SELIC %	SELIC % (year)
200501	804,197	697,635	146,07	0,39	0,33	1,63	17,74
200502	744,876	707,193	146,07	0,3	0,4	1,2	18,25
200503	760,202	753,673	146,07	0,85	0,99	1,37	18,75
200504	803,607	749,031	160,06	0,86	0,51	1,69	19,24
200505	825,605	734,022	160,06	-0,22	-0,25	1,35	19,51
200506	802,645	759,338	160,06	-0,44	-0,45	1,37	19,75
200507	813,297	793,983	165,79	-0,34	-0,4	1,8	19,73
200508	832,494	827,001	165,79	-0,65	-0,79	1,44	19,75
200509	829,390	834,002	165,79	-0,53	-0,13	1,37	19,74
200510	843,592	846,600	173,95	0,6	0,63	1,71	19,48
200511	858,487	811,396	173,95	0,4	0,33	1,6	18,98
200512	839,470	804,197	173,95	-0,01	0,07	1,01	18,49

Appendix A: (Continued)

Table A-1 (Continued)

Explanatory Variables							
				Production			
	Dollar Price (Real)	IBOVESPA	Cellulose	Basic	Rubber		
Year/month	Buyingx10	Closing Index/1000	Paper	Metallurgy	Plastic	Impression	Food
200201	23,058	13,872	99,17	13,62	10,68	0,19	3,53
200202	24,153	12,658	93,31	14,34	10,53	0,20	3,29
200203	23,588	14,414	100,46	14,97	10,81	0,19	3,15
200204	23,212	13,467	99,5	15,30	11,62	0,17	3,41
200205	23,762	12,538	95,73	16,04	11,65	0,16	4,29
200206	25,405	12,659	94,7	14,12	10,71	0,16	5,11
200207	28,587	10,892	100,7	17,03	10,92	0,17	5,42
200208	33,267	9,75964	106,26	16,17	11,01	0,19	5,63
200209	30,278	10,378	102,67	17,84	10,97	0,21	5,25
200210	37,459	8,99753	106,59	19,18	11,95	0,26	6,04
200211	36,105	10,14005	102,41	18,56	11,50	0,23	4,55
200212	36,152	10,67306	98,43	16,25	10,54	0,18	3,91
200301	35,216	11,60298	102,22	16,37	11,33	0,18	3,47
200302	34,922	10,91001	98,47	15,57	10,75	0,19	3,13
200303	35,629	10,28061	105,35	16,98	11,09	0,20	3,09
200304	33,351	11,592	105,5	16,57	10,62	0,18	3,13
200305	29,151	12,5567	102,99	17,51	11,01	0,17	4,09
200306	29,772	13,22878	103,35	14,08	11,00	0,17	4,7
200307	28,435	13,291	104,64	16,77	10,94	0,16	4,9
200308	29,998	13,12981	106,72	16,18	11,57	0,18	5,24
200309	29,832	15,35212	108,99	17,59	11,36	0,19	5,25
200310	29,026	16,57874	113,21	18,18	12,42	0,25	5,51
200311	28,551	18,51716	109,43	17,96	11,79	0,30	4,33
200312	29,333	20,5206	106,98	14,90	11,14	0,32	3,56
200401	28,854	22,444	113,82	16,27	11,70	0,20	3,39
200402	29,478	21,786	107,87	16,50	11,05	0,16	3,15
200403	28,937	22,498	118,62	18,46	12,32	0,21	3,22
200404	28,896	22,64707	113,39	17,54	11,18	0,18	3,12
200405	29,561	19,70858	117,22	18,32	11,97	0,17	4,1
200406	31,559	19,545	112,32	16,82	12,23	0,17	4,98
200407	30,739	21,34867	121,24	19,08	12,36	0,16	5,07
200408	30,458	22,372	122,21	19,75	12,98	0,19	5,49
200409	29,29	22,51287	120,89	20,93	12,88	0,19	5,62
200410	28,505	23,77702	124,6	21,12	12,66	0,21	5,47
200411	28,582	23,27298	114,91	21,13	12,54	0,27	5,08
200412	27,137	25,2347	117,49	18,28	11,69	0,29	4,13

Appendix A: (Continued)

Table A-1 (Continued)

Explanatory Variables							
				Production			
	Dollar Price (Real)	IBOVESPA	Cellulose	Basic	Rubber		
Year/month	Buyingx10	Closing Index/1000	Paper	Metallurgy	Plastic	Impression	Food
200501	26,674	2,572,201	119,04	17,97	12,02	0,26	3,38
200502	26,122	2,414,946	110,35	17,90	11,70	0,21	3,1
200503	26,003	2,772,998	123,76	19,88	12,55	0,20	3,09
200504	26,542	2,677,383	117,61	19,14	12,20	0,20	3,46
200505	25,138	24,704	123,03	19,29	12,53	0,21	4,26
200506	24,278	2,594,883	116,83	16,59	12,47	0,22	5
200507	23,451	2,531,144	123,29	18,95	11,78	0,20	4,87
200508	23,777	2,629,807	121,2	19,21	12,78	0,23	5,6
200509	23,615	2,796,219	120,09	20,11	12,14	0,22	5,36
200510	22,331	3,185,613	122,37	19,50	11,97	0,23	5,61
200511	22,508	3,089,971	120,39	19,40	12,06	0,29	4,97
200512	22,169	3,261,718	131,98	20,04	12,84	0,38	4,44

Appendix A: (Continued)

Table A-2 F value, Critic Value F_0 for $P(F>F_0) = 0.05$

Lib. Degree of the Denominator	Lib. Degree of the Numerator								
	10	12	15	20	24	30	40	60	120
1	242	244	24.6	248	249	250	251	252	253
2	19.4	19.4	19.4	19.4	19.5	19.5	19.5	19.5	19.5
3	8.79	8.74	8.70	8.66	8.64	8.62	8.59	8.57	8.55
4	5.96	5.91	5.86	5.80	5.77	5.75	5.72	5.69	5.66
5	4.74	4.68	4.62	4.56	4.53	4.50	4.46	4.43	4.40
6	4.06	4.00	3.94	3.87	3.84	3.81	3.77	3.74	3.70
7	3.64	3.57	3.51	3.44	3.41	3.38	3.34	3.30	3.27
8	3.35	3.28	3.22	3.15	3.12	3.08	3.04	3.01	2.97
9	3.14	3.07	3.01	2.94	2.90	2.86	2.83	2.79	2.75
10	2.98	2.91	2.85	2.77	2.74	2.70	2.66	2.62	2.58
11	2.85	2.79	2.72	2.65	2.61	2.57	2.53	2.49	2.45
12	2.75	2.69	2.62	2.54	2.51	2.47	2.43	2.38	2.34
13	2.67	2.60	2.53	2.46	2.42	2.38	2.34	2.30	2.25
14	2.60	2.53	2.46	2.39	2.35	2.31	2.27	2.22	2.18
15	2.54	2.48	2.40	2.33	2.29	2.25	2.20	2.16	2.11
16	2.49	2.42	2.35	2.28	2.24	2.19	2.15	2.11	2.06
17	2.45	2.38	2.31	2.23	2.19	2.15	2.10	2.06	2.01
18	2.41	2.34	2.27	2.19	2.15	2.11	2.06	2.02	1.97
19	2.38	2.31	2.23	2.16	2.11	2.07	2.03	1.98	1.93
20	2.35	2.28	2.20	2.12	2.08	2.04	1.99	1.95	1.90
21	2.32	2.25	2.18	2.10	2.05	2.01	1.96	1.92	1.87
22	2.30	2.23	2.15	2.07	2.03	1.98	1.94	1.89	1.84
23	2.27	2.20	2.13	2.05	2.01	1.96	1.91	1.86	1.81
24	2.25	2.18	2.11	2.03	1.98	1.94	1.89	1.84	1.79
25	2.24	2.16	2.09	2.01	1.96	1.92	1.87	1.82	1.77
26	2.22	2.15	2.07	1.99	1.95	1.90	1.85	1.80	1.75
27	2.20	2.13	2.06	1.97	1.93	1.88	1.84	1.79	1.73
28	2.19	2.12	2.04	1.96	1.91	1.87	1.82	1.77	1.71
29	2.18	2.10	2.03	1.94	1.90	1.85	1.81	1.75	1.70
30	2.16	2.09	2.01	1.93	1.89	1.84	1.79	1.74	1.68
40	2.08	2.00	1.92	1.84	1.79	1.74	1.69	1.64	1.58
60	1.99	1.92	1.84	1.75	1.70	1.65	1.59	1.53	1.47
120	1.91	1.83	1.75	1.66	1.61	1.55	1.50	1.43	1.35
∞	1.83	1.75	1.67	1.57	1.52	1.46	1.39	1.32	1.22

Table A-3 Correlation Total Demand (V4), High Electro-Intensive Industrial Production Index (V7), Medium Electro-Intensive Industrial Production Index (V8), Low Electro-Intensive Industrial Production Index (V9)

	Correlations (PlanilhaRegress_mod1.sta)			
Variable	Total	Intensidade	Intensidade	Intensidade
Total	1,000000	0,877432	0,749174	0,813373
Intensidade	0,877432	1,000000	0,862877	0,913147
Intensidade	0,749174	0,862877	1,000000	0,927209
Intensidade	0,813373	0,913147	0,927209	1,000000
V4**2	0,998888	0,877450	0,749920	0,815119
LN-V4	0,998819	0,875457	0,746538	0,809746
1/V4	-0,995162	-0,871369	-0,741887	-0,804127
V7**2	0,876097	0,999316	0,861015	0,909712
LN-V7	0,877593	0,999285	0,863393	0,915212
1/V7	-0,876498	-0,997086	-0,862472	-0,915808
V8**2	0,748084	0,861041	0,999447	0,923536
LN-V8	0,749589	0,863883	0,999446	0,929908
1/V8	-0,749344	-0,864067	-0,997791	-0,931617
V9**2	0,820152	0,916712	0,930006	0,998911
LN-V9	0,804980	0,907601	0,922128	0,998897
1/V9	-0,795077	-0,900140	-0,914805	-0,995590

Appendix A: (Continued)

Table A-4 Correlation Total Demand (V4), CDD (V10), Industrial Production Index (Paulista) (V11), Industrial Production Index (Brazil) (V12)

Variable	Correlations (PlanilhaRegress_mod1.sta)			
	Total	CDD	Ind (Paulista)	Industrial BR
Total	1,000000	-0,022552	0,697013	0,830912
CDD	-0,022552	1,000000	-0,303553	-0,181545
Ind (Paulista)	0,697013	-0,303553	1,000000	0,937296
Industrial BR	0,830912	-0,181545	0,937296	1,000000
V4**2	0,998859	-0,017768	0,700659	0,832535
LN-V4	0,998785	-0,028161	0,692000	0,827265
1/V4	-0,995017	0,034538	-0,685535	-0,821460
V10**2	-0,094140	0,940500	-0,243572	-0,172063
LN-V10	0,098837	0,794033	-0,213002	-0,081173
1/V10	-0,066126	-0,268372	0,026261	-0,010162
V11**2	0,700389	-0,288299	0,998762	0,933799
LN-V11	0,692474	-0,318221	0,998781	0,938447
1/V11	-0,686896	0,332088	-0,995206	-0,937319
V12**2	0,833462	-0,171443	0,939358	0,999216
LN-V12	0,827249	-0,191661	0,933799	0,999202
1/V12	-0,822488	0,201667	-0,928856	-0,996794

Appendix A: (Continued)

Table A-5 Correlation Total Demand (V4), Industrial Consumption (Sao Paulo) (V13), Received Days (Faturados) (V14), Last Month Consumption (t-1) (V15)

	Correlations (PlanilhaRegress_mod1.sta)			
Variable	Total	Industrial SP	Faturados	(t-1)
Total	1,000000	0,856893	0,171412	0,862760
Industrial SP	0,856893	1,000000	0,240786	0,687840
Faturados	0,171412	0,240786	1,000000	0,190039
(t-1)	0,862760	0,687840	0,190039	1,000000
V4**2	0,998888	0,860356	0,169125	0,860225
LN-V4	0,998819	0,851319	0,173601	0,863613
1/V4	-0,995162	-0,843529	-0,175611	-0,862610
V13**2	0,857209	0,998855	0,231540	0,690601
LN-V13	0,854778	0,998858	0,249667	0,683883
1/V13	-0,850937	-0,995471	-0,258051	-0,678816
V14**2	0,174208	0,237304	0,999801	0,193027
LN-V14	0,168557	0,244179	0,999800	0,186994
1/V14	-0,165645	-0,247474	-0,999200	-0,183893
V15**2	0,861162	0,691904	0,188293	0,998712
LN-V15	0,862268	0,682299	0,191494	0,998656
1/V15	-0,859580	-0,675264	-0,192650	-0,994547

Appendix A: (Continued)

Table A-6 Correlation Total Demand (V4), Last Year Consumption (t-12) (V16), GDP (Billions) (V17) and IGPM (V18)

Variable	Correlations (PlanilhaRegress_mod1.sta)			
	Total	(t-12)	Billions	IGPM
Total	1,000000	0,380014	0,900588	-0,037581
(t-12)	0,380014	1,000000	0,382587	-0,571454
Billions	0,900588	0,382587	1,000000	-0,207016
IGPM	-0,037581	-0,571454	-0,207016	1,000000
V4**2	0,998859	0,394467	0,898336	-0,054510
LN-V4	0,998791	0,364227	0,900605	-0,019953
1/V4	-0,995053	-0,347235	-0,898202	0,001811
V16**2	0,367218	0,998374	0,363966	-0,547273
LN-V16	0,390068	0,998486	0,398302	-0,592678
1/V16	-0,397519	-0,994192	-0,411151	0,610883
V17**2	0,900524	0,405453	0,997825	-0,231862
LN-V17	0,897301	0,356489	0,997692	-0,177809
1/V17	-0,890491	-0,327668	-0,990621	0,144795
V18**2	-0,026960	-0,482347	-0,213222	0,945903
LN-V18	0,124814	-0,480856	0,038476	0,843051
1/V18	-0,337919	0,214394	-0,343674	-0,431499

Appendix A: (Continued)

Table A-7 Correlation Total Demands (V4), IGP-DI (19), SELIC Rate (V20) and Annual SELIC Rate (V21)

Variable	Correlations (PlanilhaRegress_mod1.sta) Total	IGP-DI	SELIC %	SELIC % (year)
Total	1,000000	-0,018842	-0,262764	-0,372332
IGP-DI	-0,018842	1,000000	-0,165312	0,209443
SELIC %	-0,262764	-0,165312	1,000000	0,627749
SELIC % (year)	-0,372332	0,209443	0,627749	1,000000
V4**2	0,998859	-0,036490	-0,262825	-0,380166
LOGV4	0,998791	-0,000638	-0,261411	-0,362939
1/V4	-0,995053	-0,017920	0,258712	0,351993
V19**2	0,015484	0,936036	-0,164095	0,192525
LOGV19	0,090349	0,863192	-0,131414	0,139617
1/V19	-0,304127	-0,538578	0,064605	-0,040907
V20**2	-0,265895	-0,112520	0,982838	0,703262
LOGV20	-0,241392	-0,241821	0,970882	0,491259
1/V20	0,197032	0,321628	-0,872641	-0,306101
V21**2	-0,355282	0,194614	0,634369	0,997221
LOGV21	-0,388953	0,221457	0,618003	0,997041
1/V21	0,404466	-0,230092	-0,605311	-0,988113

Table A-8 Correlation Total Demand (V4), Dollar Rate (Buying) (V22), IBOVESPA Index (Fechamento) (V23) and Cellulose and Paper Industry Production Index (V24)

Variable	Correlations (PlanilhaRegress_mod1.sta)			
	Total	Buying	Fechamento/1000	Ind.Celulose e Papel
Total	1,000000	0,142509	0,676497	0,859464
Buying	0,142509	1,000000	-0,388139	-0,007769
Fechamento/1000	0,676497	-0,388139	1,000000	0,830213
Ind.Celulose e Papel	0,859464	-0,007769	0,830213	1,000000
V4**2	0,998888	0,120894	0,683517	0,861087
LN-V4	0,998819	0,164740	0,667254	0,855544
1/V4	-0,995162	-0,187317	-0,655738	-0,849170
V22**2	0,106899	0,997134	-0,422925	-0,050390
LN-V22	0,180346	0,996968	-0,348351	0,037398
1/V22	-0,219157	-0,987832	0,304678	-0,083619
V23**2	0,695235	-0,355788	0,993455	0,834191
LN-V23	0,639025	-0,431198	0,992807	0,808139
1/V23	-0,583318	0,481546	-0,970460	-0,767067
V24**2	0,858880	-0,022020	0,833645	0,999274
LN-V24	0,858800	0,007287	0,824974	0,999250
1/V24	-0,856826	-0,023044	-0,817905	-0,996962

Table A-9 Correlation – Total Demand (V4), Basic Metallurgy Industry Production Index (V25), Plastic Production Industry Production Index (V26), Edition and Impression Industry Production Index (V27)

	Correlations (PlanilhaRegress_mod1.sta)			
Variable	Total	Básica	Plastico	e Impressão
Total	1,000000	0,892087	0,844351	0,381713
Básica	0,892087	1,000000	0,807612	0,268928
Plastico	0,844351	0,807612	1,000000	0,252070
e Impressão	0,381713	0,268928	0,252070	1,000000
V4**2	0,998888	0,892212	0,850189	0,377641
LOGV4	0,998819	0,890028	0,836209	0,383855
1/V4	-0,995162	-0,885879	-0,825687	-0,383921
V25**2	0,891926	0,997767	0,815229	0,271012
LOGV25	0,888098	0,997734	0,795952	0,265009
1/V25	-0,880080	-0,990997	-0,780552	-0,259367
V26**2	0,844968	0,809180	0,999617	0,246043
LOGV26	0,843172	0,805482	0,999620	0,257747
1/V26	-0,841447	-0,802812	-0,998490	-0,263051
V27**2	0,360807	0,231272	0,227449	0,994930
LOGV27	0,397392	0,301226	0,271327	0,994690
1/V27	-0,406913	-0,326553	-0,284179	-0,979027

Appendix A: (Continued)

Table A-10 Correlation Total Demands and Food Industry Production Index

Variable	Correlations (PlanilhaRegress_mod		
	Total	Var28	V4**2
Total	1,000000	0,341323	0,998888
Var28	0,341323	1,000000	0,341958
V4**2	0,998888	0,341958	1,000000
LN-V4	0,998819	0,340276	0,995423
1/V4	-0,995162	-0,338759	-0,989443
V28**2	0,349568	0,997188	0,350384
LN-V28	0,330490	0,997259	0,330991
1/V28	-0,317519	-0,989389	-0,317955