To the Graduate Council:

I am submitting herewith a dissertation written by Alexandre Almir Ferreira Rivas entitled "The Manaus Free Trade Zone and Deforestation in the State of Amazonas." I have examined the final copy of this dissertation for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy, with a major in Economics.

James R. Kahn, Major Professor

We have read this dissertation
and recommend its acceptance:

Accepted for the Council:

Associate Vice Chancellor and
Dean of the Graduate School

THE MANAUS FREE TRADE ZONE AND DEFORESTATION IN THE STATE OF AMAZONAS

A Dissertation

Presented for the

Doctor of Philosophy

Degree

The University of Tennessee, Knoxville

Alexandre A. F. Rivas

May, 1998

DEDICATION

This dissertation is dedicated to my wife

Maurizia Muccini

my son

Gabriel Muccini Rivas

whose love and patience were fundamental to this achievement,

and to my mother

Luzanira Ferreira Rivas (*in memorium*).

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ABSTRACT

Tropical deforestation has gained worldwide attention because of the rapid pace at which it is happening. Continued destruction of tropical forests has been pointed out as an important cause of global warming. Tropical deforestation also affects preservation of indigenous populations, richness of biodiversity and supply of ecological services as a whole for present and future generations.

Brazil has the largest continuous tropical rain forest in the planet. The country has been charged with destroying its forests, especially the Amazonian rain forest. This destruction was said to be happening due to myopic government policies that promote massive migration to Amazonia and unplanned and inadequate land use.

This study looked at one Brazilian policy to promote economic growth in the Manaus Free Zone, which is located in the State of Amazonas. A theoretical dynamic model is developed and tested empirically using OLS regressions for 1980 and 1985. The results showed that the policy contributed to economic growth of the State and that this growth had relatively low impact on deforestation.

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CHAPTER 1

INTRODUCTION

Preoccupation with the environment and use of natural resources has grown steadily. Pollution, soil degradation, global changes, and tropical deforestation are topics driving the increasing concern about this issue. Pollution is usually associated with industrial and urban activities. Soil degradation happens due to inappropriate land use, deforestation, and changes in the hydrological cycle, among others reasons. Global changes usually have to do with green house gases emissions (e.g.: CO_2) and depletion of the ozone layer. Continued destruction of tropical forests has been pointed out as an important cause of global warming. Tropical deforestation also affects preservation of indigenous populations, richness of biodiversity and supply of ecological services as a whole for present and future generations.

It is in this scenario that nations seek economic growth. Grossman and Krueger (1995) pose the question of whether continued economic growth will ever bring greater harm to the earth's environment or ameliorate ecological problems. They say that the answers to these questions are critical for the design of appropriate development strategies for lesser-developed countries. Environmental problems can undermine economic development. The World Bank Report (1992) states that there are two ways in which this harm can happen. First, environmental quality is itself part of the improvement

in welfare that is attempted through development. Second, environmental damage can undermine future productivity.

Among the myriad of environmental problems we face, destruction of tropical forests has received worldwide attention. This attention is because of the unique role tropical forests play in evolutionary and ecological terms, the diversity of functions they serve; and the accelerating threat to their existence. According to Pearce and Brown (1994), between 1980 and 1990 the total estimated deforested area of tropical forests was 15.4 10^6 ha per year. The corresponding rate for Latin America was 7.4 10^6 ha, and tropical South America was 6.2 10^6 ha. The authors argue that

> The fundamental causes leading to tropical deforestation are competition between human and non-humans for the remaining ecological niches on land and coastal regions. This cause is associated with the rapid expansion in population growth in developing countries, 'failures' in the working of the international and national economic systems, various sorts of incentives such as those from governments and big business, and international indebtedness (p. 9).

It has been generally accepted that deforestation happens as a result of a complex interaction among the economic, social and physical environments. An alternative approach to understanding tropical deforestation can be the examination of the subject at each country (or local) level.

Purpose of the Study

The goal of this study is to contribute to the understanding of local factors leading to tropical deforestation in the South American context. More specifically, the research looks at the relationship of economic growth and deforestation in Amazonas State, which is the largest Brazilian Amazonian State. The goal will be accomplished through a descriptive analysis of aggregate income evolution and a formal modeling of some micro effects intuitively believed to link both economic growth and deforestation. The latter task is accomplished by developing a theoretical model and testing it econometrically.

Brazil and Its Tropical Forest

Brazil has the largest continuous tropical rain forest in the planet. The country has twenty-seven states and the Federal District. Brazil is dived into five regions: North, Northeast, South, Southeast, and Center-West (Figure 1). Among the Amazonian South American countries, Brazil has the greatest share of the forest. Aragón (1993) shows that Brazilian Amazonia covers 61.3% of the country's surface and 67.2% of Pan-Amazonia. INPE's (1997) data show that the percentage extent of deforestation in Brazilian Legal Amazonia in August of 1994 was 469,978 Km^2. This value represented about 9.2% of the area [1].

[1] Legal Amazonia was defined by Law 5,173 of 10/27/66 which comprehends the states of Acre, Amapá, Amazonas, Pará, Rondônia, Roraima, Tocantins and part of the states of Goiás (presently Tocantins), Maranhão and Mato Grosso (see Figure 1).

In the late 1950s, Brazil engaged in aggressive development policies. In the early 1960s, the economy lost its dynamism. By 1968, the economy had started a period of rapid growth. It lasted for almost seven years. The first and second oil shocks along with increased indebtedness involved the country in a long and difficult economic crisis. Social problems started worsening as a result of the rapid urbanization of the country, impoverishment of the rural sector, and increasing inequality of income distribution.

The Brazilian government viewed Amazonia as one of the alternatives to minimize its emerging problems. The region was viewed as an empty space available for use, which required protection due to its geo-political position and richness of resources. A series of governmental actions started to be taken. As a consequence of increasing international awareness on the importance of the environment and consequences of its misuse, Brazil was emphatically charged with being destroying its forests, especially the Amazonian rain forest. This destruction was said to be happening due to myopic government policies that promote massive migration to Amazonia and unplanned and inadequate land use.

As noted by Baer (1995), deforestation in Amazonia, which peaked in 1987, was largely concentrated in the Amazonia periphery. Data presented by the author show that in 1990, 385.5 10^6 Km^2, or 93.9 percent of the total area cleared, was located there. In the core region only 24.9 10^6 Km^2 had been deforested (Figure 1)[2].

[2] Amazonia Core: Includes the states of Amapá, Amazonas and Roraima. Amazonia Periphery: Includes the states of Acre, Maranhão, Mato Grosso, Pará, Rondônia, and Tocantins.

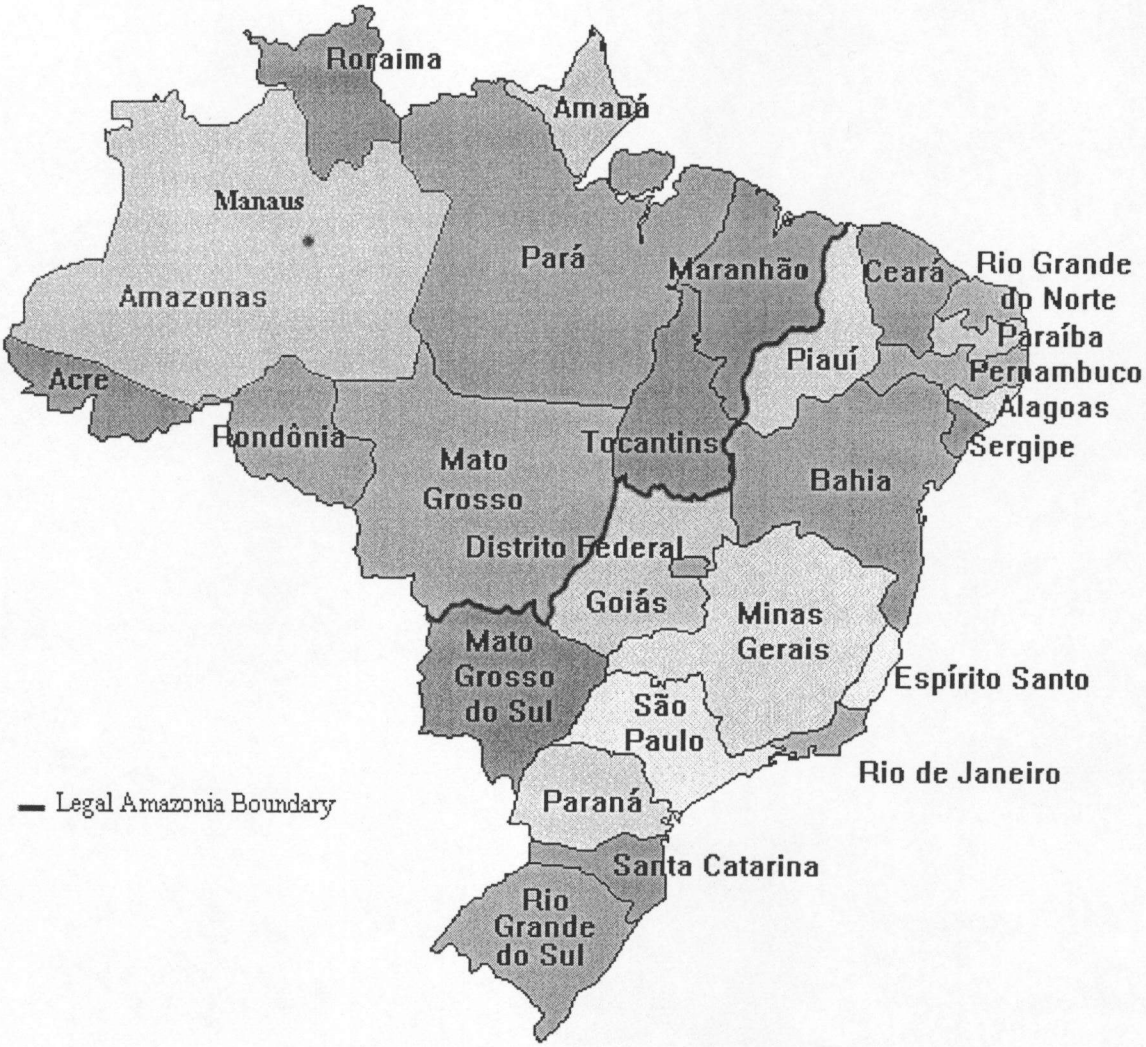


Figure 1 – Brazil and the Legal Amazonia

Description of the Problem

Many studies have been performed trying to explain the causes and sources of tropical deforestation around the world. Studies like Billsborrow and Geores (1994), and Pearce and Brown (1994) attempt to understand the problem from a general global point of view. Others like Southgate, Sierra, and Brown (1991); Lombardini (1994); Osgood (1994); Kummer and Sham (1994); and Persson (1995) have looked at the problem from the smaller countries' perspectives. Although these studies are very important, more understanding must be drawn from South American countries, which have the largest continuous tropical forest of the world. Destruction of the South American tropical forest has large impacts on the global and regional natural and economic systems.

There is not a substantial bibliography about the *economics* of South American deforestation. Most related studies look at the problem from the natural sciences perspective and/or are essentially descriptive (Bedoya, 1985 and Almeida and Campari, 1995). At the Brazilian level, only Reis and Margulis (1991), Reis and Guzmán (1994), and Wiebelt (1995) look at the problem from the economic perspective. When local causes leading to deforestation and more disaggregation is sought, there is virtually no research about the economics of natural resources in Amazonia. This is a problem because Amazonia has continental dimensions, and sources of deforestation can be very complex even at an individual state level. Many Amazonian states are larger than some European countries; this is the case of the Amazonas State.

Amazonas is the largest state of the region, and it is the one presenting lower deforestation rates. This state hosts one of the main important federal development policies for the region, the Manaus Free Zone (MFZ). Conceptually, the free zone was supposed to promote industrial development and to induce the use of regional natural resources. The policy was effective through an array of fiscal incentives at all government levels.

One can attribute the low deforestation rates in Amazonas to many reasons. Absence of a good road network has usually been pointed out as the main factor. This can be an important point. However, the free zone had strong power on the demographic redesign of the state and improved the state level of income. Considering that out-of-state in-migration is not modeled in this study, these two factors together might have contributed for the acceleration of urbanization and lessened the pressure on alternative use of the natural resources. For example, urbanization increased the size of local markets. Markets with higher income found comparative advantages in importing food from elsewhere. This fact might have minimized the incentives to convert forest into agricultural lands.

The World Development Report 1992 defines sustainable development as a way to meet the needs of the present generation without compromising the needs of future generations. Thus, sustainability is a dynamic process. To know the optimal development path is crucial for the environment and economy. The free zone program has promoted increasing urbanization and development of markets. A number of factors can affect the performance of the local/regional economy. Some of these factors are the national and

international demand for regional products, a country's macroeconomic performance, income changes and political facts. This will promote changes in the pattern of income. As they happen, comparative advantage may vanish or be reinforced and put more or less pressure on natural resources. In addition, continuous urban growth also brings many urban environmental problems. Such problems also affect welfare and economic and environmental sustainability.

Statement of the Problem and Objectives

This study investigates the dynamic relationship between the Manaus Free Zone and its contribution to Amazonas economic growth and the use of extractive natural resources. It looks at the role of the federal tax exemption as a mechanism to promote economic growth through urban development and its effects on the pattern of use of some natural resources, particularly forest resources.

The primary objectives are the following:

1. To examine the effect of tax exemption as an economic instrument to promote economic growth.
2. To test the effect of economic growth on the pattern of use of extractive natural resources, particularly forest resources.

Tax incentives activated the state economy. Even during economic difficulties faced by the rest of the country, the free zone kept a relatively good level of activity. However, the continuation of fiscal incentives can lead to many problems like the

distortion of markets, inefficient operation of firms, exacerbation of both inter and intrastate immigration and use of natural resources, and increasing urban problems. At the same time, the policy has contributed for the attainment of other non-economic objectives such as geo-political and strategic interests.

The federal program promoting development of western Amazonia through the Manaus Free Zone was based on clearly stated on its objectives that economic development should promote the use of local/regional resources as an important input. Use of these resources could have happened in two different ways: One, as a direct or indirect input in the industrial process. For example, TVs and audio systems cases could have been made from regional hardwood; plastic inputs could have been manufactured from regional extraction and refinement of oil, and watchbands for wristwatches could have been made from leather produced locally. Two, more economic activity would have implied an increase in both urban population and the demand for food which could have been supplied by local pre-existent and new farmers.

In one way or another, both channels would have required changes in the land use pattern and a diversification and increases in the intensity of extraction of natural resources. Food production requires land for plantations, which imply in forest clearing. Use of hardwood for furniture and case for video and audio systems would have required diversification an increase in the intensity of use of different types of precious hardwood, which could mean more deforestation due to unsustainable logging. Leather for watchbands requires cattle raising, which requires more land for pasture. Thus,

considering this scenario higher level of economic activity could have been associated with more use of natural resources, particularly forest resources.

This study expects to contribute to the understanding and examination of alternatives to promote regional sustainable development in Amazonia. Knowledge of the factors promoting or driving economic growth in that portion of the planet can help governments in the decision-making process to opt for alternatives with more potential to succeed both from the economic and environmental perspective. For example, economic incentives promoting urban development can determine the rural-urban migration pattern.

Adequate policies can help to improve quality of life in tropical areas without creating disproportional population growth. Over population can diminish the quality of life in both urban and rural sectors. Due to interactions, there will be no rural sustainability without urban sustainability and vice-versa. Thus, government policies and economic instruments desired to promote urban growth can be crucial for the way natural resources and quality of life will be affected.

Finally, the research expects to contribute to the understanding of the long-standing debate on whether or not the policies associated with the MFTZ were a potential Pareto improvement from the national perspective.

The plan of the study is as follows: Chapter 2 reviews the literature about aspects related to the historic, economic and environmental background. Chapter 3 describes the basic structure for economic incentives for the Manaus Free Zone. In Chapter 4 the economy of the Amazonas State is modeled in a dynamic framework and the theoretical support for econometric testing in Chapter 4 is then established. Chapter 5 develops the

argument to support the hypothesis that economic incentives promoted economic growth. Chapter 6 presents the empirical estimations. Chapter 7 presents the result and discussion and Chapter 8 concludes the study.

CHAPTER 2

LITERATURE REVIEW AND SUPPORTIVE EVIDENCE

This chapter starts by giving some historical background in order to contextualize the problem presented above. It briefly states some of the main Federal Government efforts to promote development and to integrate the North Region, especially its western side, to the Brazilian economy. Then, it will be shown that government intervention changed the demographic pattern of the region, and the main fiscal incentives given to the MFZ will be described. Finally, the last section presents some characteristics of the Amazonian environment and some of its environmental problems. As much as possible, this review will focus on the Amazonas State.

Amazonia and the Brazilian Government Policy

This section is based on the work of Bahiana (1991). The insertion of the Amazonian region in the national context happened progressively through the action of the Brazilian federal government. Bahiana divided the recent history of the region into five broad periods:

- From 1920 to 1940: regional stagnation and the search for diversification of actions in the region.

- From 1940 to 1954: beginning of the federal intervention in the region.

- From 1955 to 1964: establishment of the basis for the integration of the region in the national context.

- From 1964 to the eighties: the expansion of the frontier, and;

- During the eighties: toward a new regional problematic.

Brazil was the main world producer of wild-rubber by the end of the last century and beginning of the current century. The northern region of the country was the sole producer of the commodity. In 1910 rubber exports reached their peak and represented 40% of total Brazilian exports. Between 1910 and 1932 the gross Amazonian product, which had rubber as the most important component, had a reduction of 97% and revenues from rubber exports then represented less than 3% of the value of 1910 rubber exports (Benchimol, 1966). By 1913 Asian production was higher than that of Brazil. The larger supply of the commodity forced continuous price drops. The impact of falling prices was progressively and deeply felt by the incipient and fragile Amazonian staple economy. From that point until 1940 the regional economy stagnated. Between 1920 and 1940 the regional population remained almost the same: 1,439,052 and 1,462,420, respectively.

The following period, 1940-1954, was characterized by the beginning of proposals looking at systematic regional planning. Getúlio Vargas, then the Brazilian president, established a series of government agencies and enterprises aiming primarily at national security issues and, secondarily, integration of Amazonia into the national economy.

Despite Vargas' initiatives, the North Region was still suffering from economic stagnation and isolation from the rest of the country. In 1953 the Brazilian Congress

passed a bill creating the federal Superintendence for the Plan of Valorization of Amazonia (SPVEA). The agency's objectives included promotion of agricultural development, best technical and efficient use of the forest, development of aquaculture and the associated industries, use of mineral resources, industrialization of regional resources, development of a transportation program, permanent recovery of flooded areas, and the establishment of energy, demography, financial, trading, teaching and research polices. Concrete outcomes of this ambitious plan were the Belém-Brasília and Acre-Brasília highways. Thus, the Federal Government was responsible for the establishment of two highway axes connecting the north to the rest of the country.

The period between 1964 and 1980 was characterized by the expansion of the national frontier, Amazonia. The military Brazilian government sought to increase its presence in the region motivated by geopolitical, development, and national security issues. The first concrete action was to give more importance and power to SPVEA and to change its name to Superintendence for Development of Amazonia (SUDAM). At the same time, the Federal Government defined the SUDAM's spatial jurisdiction as the Legal Amazonia.

During this period many regional projects were carried out. In 1967 the Manaus Free Zone in the Amazonas State gained legal power and started its operation. The 'Amazonia Operation', 1965-1967, sought the effective northern integration with the national complex. Some existing highways were improved and new ones opened (e.g.: Transamazônica). This highway network opened the way for large colonization, agricultural, ranching, logging and mineral projects.

Government actions along the above period transformed Amazonia from a relatively isolated area to a frontier in expansion. During the eighties, large colonization projects such as the POLONOROESTE[3] were still carried out. The government's objective was to promote regional socioeconomic development and to alleviate social problems in other parts of the country stimulating migration to Amazonia.

Bahiana concludes that after forty years of government intervention, Amazonia was substantially integrated to the rest of the country; however, the process also generated an important perceived set of equivalencies: the North Region is equivalent to Amazonia, which is equivalent to national environmental issues. The reasoning for this analogy comes from the fact that Amazonia lies entirely in that region which is also the last Brazilian frontier. Because Amazonia also constitutes an important natural asset for the country economic and demographic growth pose a serious threat to its conservation.

The next two sections will review some demographic changes that happened in the region and its environmental characterization. Demographic changes will be described starting from the national to the Amazonas State level. The environmental characterization will present some physical and geographic aspects of Amazonia as well as some of the regions' main environmental problems

[3] POLONOROESTE was a federal plan to rebuild and pave existent highways and to promote small farmers colonization in Rondônia State and the Center-West Region of Brazil.

Demographic Changes

Government intervention in Amazonia changed the region's demographic profile. The region became the new Brazilian frontier and a kind of escape valve for other Brazilian socioeconomic problems. Policies like the POLONOROESTE colonization program, Manaus Free Zone (MFZ), the Superintendence for Development of Amazonia's (SUDAM), fiscal incentives, husbandry expansion, and projects like Jari[4] and the Transamazônica highway contributed significantly to change the scenario. The process can be seen from different perspectives, looking at the national, regional and state levels.

This section goes over a brief description of population changes that happened in Amazonia until 1996. It begins by looking at the national scenario, then moves towards the case of Amazonas State. This orientation will be particularly important because it describes the connections among policies, demographical changes and their impact on environmental and natural resources at the state level.

As pointed out by Palo (1994), *coetaris paribus,* growing human populations create increasing demand for food, clothing, energy, shelter, and services of health and culture, which adds pressure on local agents of deforestation. Barcelos and Costa (1991) state that the change in Amazonia's profile was due to land availability, discovery of mineral reserves, and federal support through fiscal incentives and special credit lines for

[4] Jari Project was a large enterprise in the Jari's river valley (Pará State) to produce cellulose, white clay mining and large-scale rice production.

some production activities and colonization projects. For Wiebelt (1995) "the 'deforestation problem' in Brazil... consists of a variety of interrelated issues. These issues are identified as regional, sectoral and macroeconomic dimensions, of which this paper has identified a regional, sectoral and macroeconomic dimension."

In the 1960s, 1970s, and 1980s Amazonia experienced profound changes in its population characteristics caused by in-migration. From a national/regional perspective, Almeida (1992) describes migration to Amazonia in two broad categories, that is, the rural and urban frontiers[5]. By frontier she means an advancement of a social movement that happens on a geographic territory in a given lapse of time.

Between 1960 and 1991 the Brazilian rural and urban frontier moved toward Amazonia. As can be seen from Table 1 the Southeast Region of Brazil was the main source of the rural exodus during the sixties. In the following decade both the South and Center-West, in addition to the Southeast, were important rural out-migration sources. During the eighties four out of the five regions of the country had their rural population drastically decreased. The Center-West had the highest decrease in rural population. The North region was the only one presenting significant increasing rural population. Thus, it is possible to infer that the northern area received part of the national migratory human contingent. Almeida (1992) continues explaining that this migration process seemed to have happened because, from one side, the old agrarians frontiers in São Paulo and

[5] The rural and urban definition used by the author is the same used by the Brazilian Statistical Agency (IBGE). Urban situation is defined as areas both urbanized and not urbanized corresponding to cities (municipal seat), villages (district seat), or isolated urban areas. Rural areas are chose outside the above limits, including small villages and nucleus.

Paraná states had exhausted due to the growing participation of large-scale soybean and sugar cane plantation. On the other hand, the Brazilian economy was growing very fast during the sixties and early seventies. In addition, the high external debt forced the country to invest in activities able to generate revenues in foreign currency. Among these activities were agriculture commodities like soybean, coffee, and sugar cane. These factors together increased the price of land in those regions inducing small farmers to sell their properties to buy bigger plots in the new frontier.

Becker (1995) and Almeida (1992) suggest that a better assessment of the dimension of the rural frontier in Brazil has necessarily to consider the urban migration aspects during the same period. Table 1 also shows that the national urbanization trend followed a relatively standard pattern. All regions presented high values for percentage change in urban population growth, but with decreasing trend over time. The exception was the North. This area showed increasing urban growth along the three decades. Now, comparing both situations, it is easy to visualize that Brazil had high urban growth in the sixties with relative decreasing trend toward the eighties. The national rural population was continuously decreasing. As a net result, Brazil became a strongly urbanized country. In 1960 the rural population represented 55.3% of the total while the urban was 44.7%. In 1991 they were 24.4% and 75.6%, respectively.

Table 1- Percentage change in Brazilian population between 1960/1991*

Region**	1970/60		1980/70		1991/80	
	Rural	Urban	Rural	Urban	Rural	Urban
North	23.27	69.84	43.79	86.72	44.49	95.00
Northeast	11.55	56.36	5.42	49.47	-3.04	46.73
South	24.36	67.48	-22.19	62.63	-19.95	38.10
Southeast	-17.32	65.88	-18.32	47.90	-15.51	28.91
Center-West	36.17	141.99	-7.80	109.84	-27.39	49.83
BRAZIL	5.90	66.39	-6.06	54.43	-7.08	37.99

Source: IBGE (1990)

* Values were calculated according to the formula: $(t_1-t_0)/t_0$.

** North: Acre, Rondônia, Amazonas, Roraima, Pará, and Amapá. Northeast: Maranhão, Piauí, Ceará, Rio Grande do Norte, Paraíba, Pernambuco, Alagoas, Sergipe, and Bahia. Center-West: Mato Grosso, Mato-Grosso do Sul, Goiás, Distrito Federal Southeast: Espírito Santo, Minas Gerais, Rio de Janeiro and São Paulo. South: Paraná, Santa Catarina and Rio Grande do Sul. See Figure 1.

Regional Level

Table 2 shows that the regional rural population in the North Region increased by almost 24% along the sixties. This trend continued even stronger during the seventies, slowing down in the subsequent decade. The Acre and Amapá states had negative increment in their rural population in the eighties; that is, people left out rural areas. The Rondônia, Pará, and Roraima states consistently contributed for increasing rural population along the three decades. Special attention can be placed on Rondônia during the seventies. Notice that the increase in rural population was almost 410%. Both Pará and Rondônia were the main target of the national colonization programs on that decade.

Table 2 – Percentage change in the North Region population between 1960-91*

States	1970/60		1980/70		1991/1980	
	Rural	Urban	Rural	Urban	Rural	Urban
Acre (AC)	24.31	81.37	8.42	122.86	-5.87	95.60
Amazonas (AM)	15.53	74.24	4.38	111.08	4.71	75.43
Amapá (AP)	57.51	79.49	37.79	66.11	-22.73	125.70
Pará (PA)	25.24	66.18	51.61	63.15	35.58	55.72
Rondônia (RO)	30.03	97.32	409.77	283.69	80.31	188.50
Roraima (RR)	44.86	43.90	30.00	178.78	152.31	188.95
Tocantins (TO)	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL	23.27	69.84	43.79	86.72	44.49	95.00

Source: IBGE (1990 and 1997)

* Values were calculated according to the formula: $(t_1-t_0)/t_0$.

In general, regional urban growth followed a different path when compared to the national behavior. Urban growth was high and increasing while the national trend was also high but decreasing over time. All states had their urban population substantially increased along the sixties and seventies. Some slow down was observed in the eighties. Rondônia and Roraima had the most significant increase in urban residents. Acre and Amazonas had their urban population increased during the seventies followed by relative decrease in the eighties. Pará had a relatively stable urban growth.

The percentage change in both rural and urban resident population increased throughout the period as compared to the rest of the country. Tables 1 and 2 show that the national movement toward the new frontier was substantially absorbed by the urban sector in all states of the region.

State Level

As Figure 2 indicates, the Amazonas State had in 1991 sixty-two municipalities. For better explanation the state is divided into thirteen sub-categories denominated micro-regions. This sub-division is the one used by the Brazilian Statistics Agency, FIBGE. Table 3 shows that during the seventies seven sub-regions had their rural population increased. The micro-region of Manaus was the one presenting a higher increase. Five areas had an actual decrease in their rural population. During the eighties eight sub-regions presented increases in their rural population. The 1980s scenario was predominantly contrasting when compared the seventies. Eight micro-regions had their

Table 3 - Percentage change in Amazonas population, by Micro-region, between 1970-91*

Micro-region	1980/70		1991/1980		1996/1991	
	Rural	Urban	Rural	Urban	Rural	Urban
Rio Negro	-1.25	0.07	53.57	130.01	-7.50	50.27
Japurá	4.51	0.70	77.36	167.01	-18.25	30.75
Alto Solimões	22.44	75.18	-5.87	172.91	42.01	12.87
Juruá	-11.08	108.13	14.33	135.35	-6.21	29.57
Tefé	30.97	102.89	62.59	175.80	32.01	24.65
Coari	20.45	60.11	-8.42	70.93	14.60	33.99
Manaus	77.66	117.22	-7.70	67.40	7.52	14.78
Rio Preto da Eva **	0	0	0	0	34.88	66.76
Itacoatiara	10.74	87.88	-12.83	48.95	0.25	19.61
Parintins	-1.31	79.76	-12.33	64.28	24.51	19.88
Boca do Acre	-8.86	83.79	22.59	67.42	-16.58	37.84
Purus	18.52	130.84	32.00	122.90	-46.92	7.80
Madeira	-0.06	198.00	5.13	69.57	-9.04	13.81
TOTAL	4.40	111.12	4.85	75.19	3.66	17.60

Source: IBGE (1990 and 1997)

* Values were calculated according to the formula: $(t_1-t_0)/t_0$.

** This micro-region did not exist until 1985

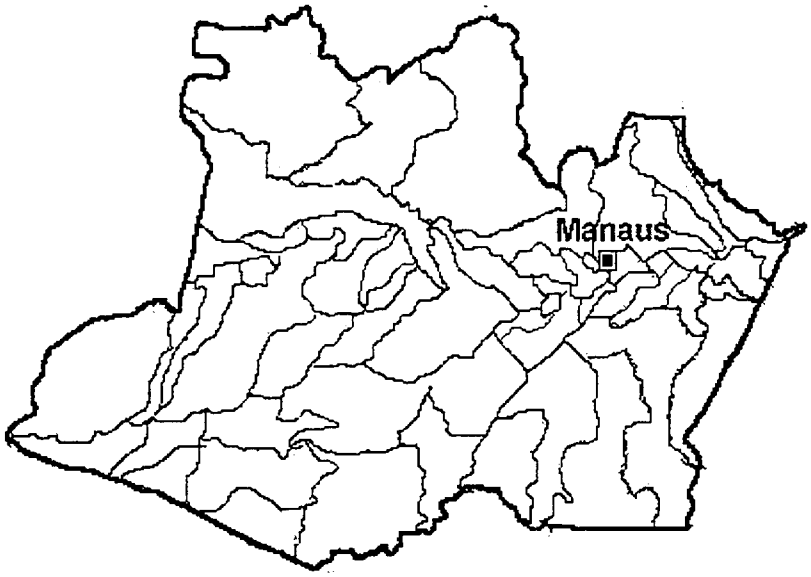


Figure 2 - 1980 Amazonas' Municipalities Network

original percentage changes in rural population signs switched. Four of them had their previous trend magnified. Except for one, micro-regions located in the central area of the state (Manaus, Coari, Itacoatiara and Parintins) presented strong decreases in rural population. All the other, excepting the Alto Solimões had their rural population increased. The overall state change in rural population between the two decades was about 10%. When compared to the national—which presented negative changes along the seventies and eighties—and the regional aggregate, Amazonas seemed to have absorbed a small fraction of the national/regional rural human migratory contingent. Other northern states seem to have played more important roles in such absorption.

As opposed to the rural case, urban growth was strong on all areas in both decades. The central area of the state which comprises six micro-regions and in 1991 had

almost 75% of the state's population, was responsible for most of its population increase[6]. Such increase was almost 110% at the end of the seventies and close to 70% in the eighties. Urbanization in the Amazonas State followed the Brazilian rather than the regional trend. That is, it was high but decreasing over time. However, the relative level of urban population change was at least twice greater than the national aggregate for each decade. When compared to rural changes in population, urban changes were extremely high at the state level.

Environmental Characterization

As stated above by Bahiana, the North Region is equivalent to Amazonia, which is equivalent to national environmental issues. Despite its exuberance, the Amazonian environment is believed to be a relatively fragile natural environment. Thus, it is important to sketch some of the main environmental characteristics and problems related to it. This section is divided in two parts. The first lists some physical and ecological characteristics of that environment. The second briefly illustrates some of its main environmental problems. Four aspects are going to be described here briefly: climate, hydrology and hydrography, vegetation and soils potentiality.

[6] See Appendix for a list of micro and meso-regions.

Climate

Almost the whole North Region has an equatorial climate. This means a high daily index of rain as its fundamental characteristic. As far as the rainy season is concerned, the region has two basic spatial modalities: super-humid and humid. On areas where the former predominates there is not a normally dry season. Areas characterized by a humid climate present one to three months of dry season during the year. The average annual temperature is between 24°C and 26°C, depending on the location (Nimer, 1991).

Hydrology and Hydrography

Due to the predominance of high pluviosity on almost all of its territory, the Amazon Basin is the richest and densest known drainage network on the planet. Collecting a great part of the world's pluviometric precipitation, the rivers in the Amazon Basin have a permanently high volume of water. The system drains about one-fifth of the planet's freshwater. The continental expression of the Amazon Basin comes from the fact that it drains approximately one fourth of the South America surface, covering nine out of the thirteen South American countries[7].

Fearnside (1993) explains that evidence shows that half of the precipitation in Amazonia comes from recycled water. The recycling process happens through the forest's evapotranspiration instead of water vapor coming from the Atlantic Ocean. This natural

[7] Bolivia, Brazil, Colombia, Equator, Guyana, French Guyana, Peru, Suriname, and Venezuela.

process involves a tremendous amount of water. One can have a feeling of its proportion by observing the Amazonas River during its high water level period.

For Brazil, the basin is very important due to at least three reasons. First, the water coming from the evapotranspiration in Amazonia also contributes to the rainfall in the central-southern Brazil. This is the area where most of the country's agricultural activity is located. According to Fearnside (1993), a simulation performed by the Goddard Institute for Spatial Research showed that water from Amazonia becomes rainfall for all over the country. The study also showed that this phenomenon does not affect climate in other continents.

The second reason is related to river navigation. This mode of transportation is possible all year long in the Amazonas river and in many of its tributaries (Soares, 1991). Finally, the system is important because of the amount of nutrients that it discharges in the Atlantic Ocean. This fact contributes to the formation of a very rich aquatic and terrestrial coastal environment that supports wildlife, subsistence and economic activities along the northern and northeastern Brazilian coast.

Vegetation

The current official classification of the Brazilian statistical agency (IBGE) divides the vegetation into ten broad categories: (1) dense ombrophyla forest, (2) open ombrophyla forest, (3) semi-deciduous seasonal forest, (4) deciduous seasonal forest (5)

savanna, (6) savanna stepic, (7) campinarana, (8) pioneer formations, (9) ecological tension, and (10) ecological refugee (Bohrer and Gonçalves, 1991).

Dense ombrophyla forest is the one without periods biologically dried all year long. Precipitation is greater than 2,300 mm and the average temperature ranges from 22 °C to 25 °C. Open ombrophyla forest occurs where the average annual temperature is about 22 °C with two to three months without rain. The semi-deciduous seasonal forest occurs where there are two defined seasons: one with rain, and the other characterized by four to six months of dry season with annual average temperature around 22 °C. The deciduous seasonal forest is the one where trees lose their leaves during a regular and well-defined dry season (from June to September). Savanna (Cerrado) appears on the periphery of the great Amazonian valley. These areas present a tropical climate with well-defined rainy period delimited by a dry season ranging from four to six months and/or with light rain. The average monthly temperature is greater than 15 °C. Savanna stepic is a kind of semi-arid vegetation and occurs where there are five to six months of dry season. In Brazil, Campinarana occurs only in Amazonia. It is a naturally-preserved and there is little scientific knowledge about it. Its occurrence is associated with very poor soil where even minimal agriculture activity is not possible. Pioneer formations are the type of vegetation occurring where soils are still in an incipient process of formation. Areas of ecological tension are those where there are, sometimes, contact between two different kinds of geological formation with strips of climate transition. Finally, there is ecological refugee vegetation. These are small areas, usually located on highlands with

very unique biological characteristics. The predominant vegetation in the Amazonas State is dense and open ombrophyla forest.

Soil Potential

Despite its large area, only a portion of the region is suitable for agricultural purposes. According to the classification presented by Souza (1991), almost 82% of the region's area have a low or inappropriate fertility level. Around 13% of it are classified as medium-high, or medium grade fertility with physical/chemical restrictions. Only 5.4% of the region have high quality soils suitable for agricultural purposes. The best quality lands are located in the state of Rondônia. Areas inappropriate for agricultural purposes are spread over the whole region, but their distribution is higher in western Amazonas. Also, many portions of low-quality land are in Amazonas, Amapá, and Roraima states. Most of Acre has a medium to high quality grade of soil. In Pará, medium to low quality soils also predominates.

The Main Environmental Problems in Amazonia

Five environmental problems will be pointed out here: deforestation, biodiversity loss, logging, mining and urban degradation. By far, deforestation has been the issue receiving more attention in Amazonia. Biodiversity loss and logging (in lower degree) are associated with deforestation. Mining is an issue involving both mining companies

and independent small miners. Urban degradation is related to the fast urban growth that happened in the last three decades.

Deforestation

From Pearce and Brown's (1994) perspective, deforestation has important economic and social impacts, and because of that, it is important to identify its causes. They argue that the proximate causes of tropical deforestation are the clearing of land for other uses such as agriculture, and unsustainable logging.

At the international level, Kahn and McDonald (1995) argue that third-world debt is an important factor in the deforestation of tropical countries. However, they also suggest that there are important microeconomic causes of deforestation, which may vary significantly from country to country.

For the Brazilian case, Baer (1995) argues that the Amazonian rain forest is being destroyed by cattle ranchers responding to government initiatives and subsidies, migrants engulfed in poverty and fleeing over-populated cities, loggers interested in precious hardwood, mining enterprises, land speculators, and hydroelectric projects.

Almeida and Campari (1995) point out that the current migration of small farmers from old to new frontiers within the Amazon poses an important threat to the forest. Small farmers in Amazonia have been responding to economic conditions that reward speculation and encourage deforestation.

Dore and Nogueira (1993), on the other hand, argue that deforestation in the Brazilian Amazonia is an integral outcome of the land tenure system, the structural and endemic inflation, and the fact that like most developing countries, Brazil has to adapt to the international market, which in the final analysis sets the prices of Brazilian exports. Along these macroeconomic lines, Almeida and Campari (1995) suggest that instability appears to fuel deforestation in two ways: First, driving up land prices and/or changes the demand for land from that of a productive factor into that of speculative asset, and second, low wages and low probability of finding a job in a depressed urban economy reduce the opportunity cost of frontier farming, encouraging settlers to continue farming and deforesting the frontier.

Some of the factors above have to do with the direct government intervention in Amazonia. Others have indirect influence on the way that the frontier is incorporated into the rest of the economy. Thus, changes in the demographical profile examined above can have some relationship with deforestation. Deforestation patterns in Amazonia can be observed from Table 4.

Between 1975 and 1994 6.65% of Legal Amazonia area was deforested. Acre, Tocantins, Maranhão, Pará, Mato Grosso and Rondônia were the states presenting high annual deforested area along the period. The latter four states were the ones with higher percentages of deforested areas. When only the North Region is considered[8], Rondônia, Acre and Pará are the ones with higher deforested areas. In 1994 Amapá, Amazonas and Roraima were the ones presenting lower percentages of deforested areas.

[8] Amazonas, Pará, Acre, Rondônia, Roraima and Amapá (Tocantins is not considered for the analysis).

Table 4 - Percentage extent of deforestation in the Brazilian Legal Amazonia (km^2)

States	1975*	1978	1988	1989	1990	1991	1992	1994
Acre	0.76	1.63	5.81	6.40	6.73	6.99	7.25	7.88
Amapá	0.11	0.14	0.56	0.70	0.91	1.19	1.21	-
Amazonas	0.05	0.11	1.25	1.38	1.41	1.47	1.52	1.57
Maranhão	23.55	19.17	27.24	27.69	28.02	28.23	28.57	28.79
Mato Grosso	1.15	2.21	7.88	8.78	9.22	9.54	10.05	11.43
Pará	3.89	4.50	10.49	11.12	11.51	11.81	12.11	12.80
Rondônia	0.51	1.76	12.58	13.33	14.05	14.51	15.46	17.63
Roraima	0.02	0.04	1.20	1.60	1.69	1.87	1.99	2.20
Tocantins	1.26	1.15	7.76	8.01	8.22	8.40	8.55	8.79
LEGAL AMAZONIA	2.55	2.98	7.39	7.86	8.13	8.34	8.61	9.20

Source: INPE (1998) http://www.inpe.br/amazonia/desflora.html

Note: Data corresponding to 1992 and 1994 do not consider areas covered by clouds on the satellite imagery. In particular, the 1994 extent of deforestation for Amapá State is not estimated herein because of cloud cover. An estimate of the deforested areas under clouds is under way. Data presented here will be soon revised, to incorporate these estimates.

*May and Reis (1993) *in* Wiebelt (1995).

Deforestation in Amazonas

As seen from Table 4, in 1993 Amazonas was the state with the lowest percentage extent of deforested area in the region. The state has 62 municipalities that can be grouped in four meso-regions. This classification is the one used by IBGE. The state is divided into meso-regions north, south, southwest, and center[9]. Table 5 shows that almost all meso-regions had relatively low deforestation between 1975 and 1988[10]. The area with higher deforestation was the Central. This is the area where the free zone is located.

[9] See Appendix for a list of meso-regions.

[10] Data at this level of disaggregation is not available for all years shown in Table 4.

Analysis at the micro-region level (not presented here) shows that the areas with increased in deforestation were municipalities receiving direct influence from Manaus. Also, it is possible to see that municipalities connected to Manaus by road or having relatively easy access by river presented the deforested area. One important fact to mention is that until 1988 the municipality of Manaus had a higher percentage of deforested area, that is, 0.053% of the state area.

Figure 3 below shows how deforestation and population changed in the past two decades. As can be seen, both had continuous increases. However, population density as well as percentage of deforested area was very low in Amazonas.

Table 5 - Percentage extent of deforestation in Amazonas State, by Meso-region (Km2)*

Meso-region	1975	1978	1988**
North	0.002	0.006	0.017
Southwest	0.019	0.028	0.050
Center	0.023	0.087	0.536
South	0.000	0.000	0.002
TOTAL	0.044	0.121	0.605

Source: Instituto de Pesquisas Economica e Aplicada and IBGE.
* Deforested meso-region area/total state area.
** The total in this column is not consistent with the value presented in Table 4. The likely reason would be difference in methodology of measurement.

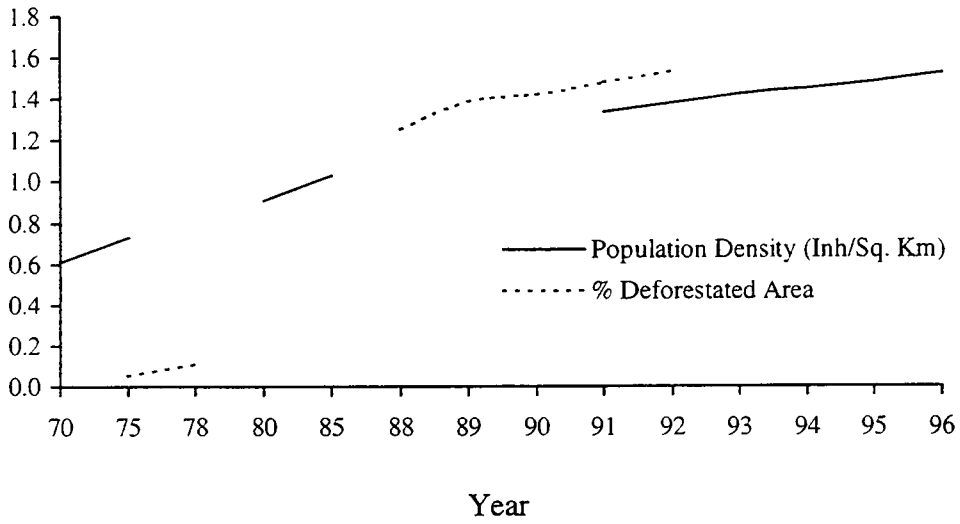


Figure 3 - Population and Deforestation in Amazonas

Biodiversity Loss

As described by IDB/UNDP/ACT (1992), the genetic legacy contained in the Amazonian ecosystem is the best example of a public good supplied by tropical forests, and its worth is probably incalculable. Despite the lack of precise scientific knowledge, it is estimated that the contents of Amazonia tropical forest biota range from 800,000 to five million species, thus accounting for 15 to 30 per cent of the total number found in the biosphere. Although the estimates are not accurate, it is believed that more than 1,000 species of plants in the Amazonian ecosystem have economic possibilities, and that at least 300 species of trees are potentially valuable as forestry resources. Even more impressive is the fact that a plot of ground measuring 0.2 hectares (less than half an acre)

near Manaus contains 505 species of trees more than two and a half meters high, as compared with fewer than 50 species in the whole of France. Similarly, more than 2,000 species of fish are found in the Amazonas River—eight times the number in the Mississippi River and ten times the total in all of the rivers of Europe combined.

Logging

As estimated by Wiebelt (1995), the logged area of Classic Amazonia soared from 1,900 Km^2 in 1980 to 7,900 Km^2 in 1989. When the Legal Amazonia is considered, the area logged increased from 2,470 Km^2 in 1980 to 8,550 Km^2 in 1989[11]. These numbers suggest that the scale of logging operations in Amazonia quadrupled in the 1980s. State data show that this increase was heavily concentrated in southern Amazonia.

Mining

Two kind of mining activities are practiced in Amazonia. One is the large-scale mining developed by big companies and the other is the small-scale mining practiced by *garimpeiros*[12]. Large-scale mining usually works as an important investment inducement. Discovery of the reserves of tin and bauxite in the mineral province of Carajás in the Pará State was responsible for large investments in that region. In addition, large-scale mine

[11] These latter figures include southern Goiás and eastern Maranhão, which are not part of the Legal Amazonia. Estimates will be affected because these areas are not heavily forested.
[12] Garimpeiros are usually small/individual independent miners.

activities greatly affect the natural environment and local socio-cultural characteristics. According to CIMA (1991), uncontrolled and undisciplined large-scale mining activities in Amazonia can cause irreversible environmental damages like destruction of genetic banks, changes in the soil structure, climatic and hydrologic changes and spread diseases.

Small-scale mining is responsible for many environmental problems. This kind of activity is not supported by adequate research. Damages associated with *garimpagem*[13] are usually derived from unplanned prospection, lack of local/regional geological knowledge, sedimentation of waterways, and mercury emissions to the environment. In the latter case, there are also direct effects on human health. CIMA (1991) points out that by 1991 there were 1,854 *garimpagem* sites in Brazil. According to official data, gold, gem and other mining activities hired about 300 thousand people.

[13] Garimpagem is the mining activity itself

CHAPTER 3

MANAUS AND ECONOMIC INCENTIVES

This chapter looks more detailed at Manaus and its free zone. The section about Manaus and the western Amazonia reviews the importance of the city for the development of the region and summarizes the Brazilian steps toward the establishment of the free zone. The section about economic incentives shows the evolution of the policy and describes the main tax incentives.

Manaus and the Western Amazonia

Manaus is the metropolis of western Amazonia and its origin and location is due to its strategic position, which facilitated the navigation and domain of that immense area. The city is located where the Solimões River meets the Negro River. This meeting forms the Amazonas River. The city is relatively equidistant both from the western and eastern Brazilian frontiers (Figure 1). For about two centuries, up to the rubber boom, the city and the western Amazonia lived in complete stagnation.

Melo and Moura (1990) explain that by the beginning of the third decade of this century the collapse of the wild-rubber economy in Amazonia caused the bankruptcy of the existing extractivist mercantilist system. For Manaus this fact meant the decline of its importance as the main commercial center and its economic stagnation. Population of

Manaus increased from 75,000 inhabitants in 1920 to 152,432 in 1960, and 283,685 in 1970. This migration process, however, was not a result of urban development. Rather, it was a result of the decline of extractivist sector.

The idea of developing western Amazonia using Manaus as the starting point got settled. Economic mechanisms were the chosen instruments. Fiscal incentives were believed to be able to transform Manaus into a big city able to attain three main objectives. First, to significantly increase the Brazilian presence in that huge sub-populated area. Second, to be the western Amazonian base for colonization. Finally, to be a sizeable market capable of inducing population growth and agriculture development.

The Manaus Free Zone

The first legal action towards the establishment of the Manaus Free Zone was in 1957[14]. Juscelino Kubitschek, then president of Brazil, created a free zone in Manaus for storage of imported merchandise to be consumed in Amazonia, or neighbor countries.

On February of 1967 the Brazilian government expanded and improved Law 3173 and created the Manaus Free Zone[15]. The free zone was defined as "an area of free trade for import and export, and special fiscal incentives able to create in the interior of Amazonia an industrial, commercial and agricultural center endowed of economic conditions to promote regional development". The conception of the Free Zone was

[14] Law n° 3173 of 06/06/1957.
[15] Law-Decree n° 288 of 02/26/1967.

based on the use of natural resources, which were supposed to give the necessary conditions for developing competitive firms in the area. The agricultural development was thought to guarantee supply of raw materials for local industries, and to be deterministic with respect to the attenuation of the rural-urban migration. In addition, it was also thought to be able to improve the rural economy and consequently to contribute for increasing exports (DNPM, 1978).

In 1968, president Costa e Silva expanded the benefits of Law n° 288 to western Amazonia[16]. The latter comprised the states of Amazonas, Acre, Rondônia, and Roraima.[17] The benefits covered capital, consumption and essential goods imported, originated, benefited or manufactured in the MFZ.

Manaus is said to be a unique kind of free zone. Around the world there are different modalities of free trade and enterprise zones. Usually, these enterprises cover relatively small geographical areas. According to the Superintendence of the Manaus Free Zone, this policy is different from related programs around the world because it follows the concept of extraterritoriality (SUFRAMA, 1993). The superintendence has jurisdiction over an immense area of the Brazilian Amazonia. This area is equivalent to 25.75 % of the national territory, which represents approximately 2.2 million square kilometers.

[16] Law n° 356 of 08/15/1967.
[17] Law-Decree n° 291 of 02/28/1967 defines western Amazonia.

The Manaus Free Zone and Tax Issues

The Manaus Free Zone is important because of its local and regional potential to promote deep regional changes. This section will describe two aspects related to the policy. First, it will present a more detailed outline of its purpose and objectives, and then will describe the main aspects of the fiscal incentive framework.

Purpose and Objectives of the Free Zone

The free zone had vital importance for regional development. By the time of its legal establishment, 1967, its relevance was also reinforced by the creation of a federal agency specially designed to manage and implement the policy. In the following year the agency gained even more power when the federal government extended the fiscal incentives for products proceeding from the free zone to be utilized in other areas of western Amazonia.

Lyra (1995) says that the effective siting of the MFZ happened in a moment when the Brazilian economy was leaving the recession of the sixties and starting a phase of fast economic growth. Thus, the objective of Brazilian industrial policy was to reach a high level of industrial growth based on two main strategies: (a) to increase significantly the exports of industrialized products, and (b) to give continuation to the process of imports substitution, especially for basic inputs and capital goods. The free zone industrial policy

fit in this general scenario mostly through the latter strategy. The emphasis was given to durable goods not produced in the country.

The main goal of transforming the MFZ into a source of regional development and an industrial and commercial center was connected to two intermediate objectives, which were the links between the regional and national industrialization processes. The first of them was to make Manaus a supplier of durable goods for domestic markets. The second was to stimulate the free zone to use inputs and capital goods produced by industries from the south of the country[18]. Besides these two points, the strategy was complemented by the following elements:

1. Use of a strong market reserve policy against international competitors for products from the MFZ.

2. Use of a set of incentives to make industrial investments in the MFZ more attractive than those in the rest of the country did.

3. Use of external economies already existent in the region and which were mainly associated to an urban center of reasonable size, Manaus, and river transportation as well as the economical infrastructure then available.

4. To give to the region a relatively autonomous federal public agency, Superintendencia da Zona Franca de Manaus (SUFRAMA), to manage the industrial and commercial policies for the MFZ.

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[18] Note that this argument diverges from what was established by Law-Decree 267. See section: The Manaus Free Zone.

Castelo Branco (1991) observes some of the results of these strategies. The industrial census for 1960 revealed that the industrial structure of Manaus was basically constituted of intermediary, petroleum derivatives, and non-durable, vegetal fiber (juta) and food products. Census data for 1970 showed only a slight increase in the relative participation of capital and durable consumer goods industries in the non-durable consumer sector. During the 1980s the scenario had changed completely. Essentially, capital and durable consumption goods composed the industrial base of Manaus. Benchimol (1989) states that as of 1988 the industrial sector ranked first within the Amazonas economy and featured 346 medium and large enterprises. These enterprises manufactured finished and semi-finished goods. Data presented by Kumi and Piani (1997) show that between 1990 and 1995 the global earnings in the industrial sector increased by almost 28%.

Fiscal Incentives

Fiscal incentives granted to the MFZ included total or partial tax exemptions and special long and short-terms credit lines. Public investment in infrastructure was also improved. Lyra (1995) presents a through description of these fiscal instruments, three of which will be reviewed here: tax on industrialized goods (IPI), import tax (II), and sales and business tax (ICMS)[19]. The first two are federal taxes while the third is a state tax. The choice of these instruments was made because of the following reasons:

[19] A value added type tax.

1. They are relatively easily adjustable to meet general macroeconomic goals.

2. They are or can be used as mechanisms to promote sectoral development.

3. They can play an important role on firm's locational decisions.

4. Finally, data for those taxes can be relatively less difficult to obtain.

Evolution of the Tax Policy

Fiscal incentives were given at the federal, state and local government levels. This section will discuss the over time changes of the fiscal policy at the federal and state level only. This is so because tax incentives granted by these levels of governments are likely to have more influence on firms' location decisions. Federal tax incentives are even more important because they were initially strong enough—along with other fiscal incentives—to influence firms' locational decisions and helped these firms to maintain their over time comparative advantage relative to the rest of the country. Thus, this section will describe the main characteristics of federal taxes, on industrialized goods (IPI) and import (II), and state tax on sales and business (ICMS).

Federal Level

Frischtak *et al.* (1994) describe that until 1974 the economic activity of the free zone was restricted to commercial transactions. The federal fiscal benefits were essentially of four types: First, exemption of II and IPI incident on input imports to be

used in the production of goods for exports and local consumption. Second, the reduction of import tax on imported inputs used in the production of goods sold to the rest of the country. Third, the exemption of IPI on domestic purchases made by companies located in the MFZ, and finally, exemption of the same tax on goods manufactured in the MFZ and sold locally and to the rest of the country.

In 1978 the minimum "Index of Nationalization for Industrial Goods" was defined and implemented. Companies were required to match it to be eligible to benefit from fiscal benefits. This index was used as an additional requisite for concession of reductions on import tax (see section about import tax below). Parallel to this mechanism was a quota system, which was applied to subsidized imports. The "Global Import Quotas" system was in effect since 1976. Attempting to stimulate the use of regional inputs, the nationalization index was revised in 1985. In 1991 the nationalization index was substituted for a new one called "Basic Productive Process" (BPP). This process was defined as the minimum set of tasks performed in manufacturing to characterize the effective industrialization of a given product. Following the opening of the Brazilian economy in 1992 and seeking to compensate the MFZ for some of its losses, the Brazilian government increased the IPI rate by 10%. This tax was applied to the import of goods having close or perfect substitutes produced in the MFZ, the increase was an additional incentive.

State Level

At the state level, there were three main incentives. First, exemption from sales tax (ICM)[20] on goods purchased domestically to be used in the MFZ. Second, fiscal credit for national suppliers corresponding to the amount of ICM due by the time the goods entered in the Amazonas State jurisdiction; and finally, total restitution of ICM due relative to acquisition of intermediary goods, and 55% or 45% for all other goods.

Lyra (1995) states that the intensity of fiscal incentives granted by the Amazonas State did not have substantial changes over time. He also states that ICM/ICMS incentives are likely to be innocuous on firms' investment decisions because the tax benefit is not strong enough to cover or minimize *investment and/or financial*[21] risks. Thus, assuming that Lyra's considerations are relevant, this study is not going to focus on ICM/ICMS incentives.

Tax on Industrialized Goods and Imports

Federal taxes played a major role for the MFZ. As already mentioned, total or partial exemption from the tax on industrialized goods and on imports were the main economic instruments.

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[20] It is an earlier version of the ICMS.
[21] Author's remark.

Tax on Industrialized Goods (IPI)

Goods industrialized in the MFZ are totally exempt from IPI. This exemption covers industrial production using regional agricultural and extractive goods in western Amazonia. All foreign or domestic inputs used in the manufacturing process in the free zone or elsewhere in western Amazonia are also exempt. The latter case includes equipment and inputs used in agriculture, cattle raising, fisheries, road, industrial and general construction, food production and medicine industry.

One category of IPI incentive proportionates potential for increase in the demand for some Amazonian natural resources. Any company in Brazil buying and using industrial input based on agricultural and extractive raw material produced in western Amazonia—goods from cattle raising activity were excluded—would be eligible for a credit. This credit is equal to the presumed IPI due on sales of those companies[22].

Lyra (1995) regards exemption of IPI as the main fiscal incentive. He notes that until recently IPI rates ranged between 0 and 40% and the mean and modal values were 14.5% and 12%, respectively[23]. Following the opening of the Brazilian economy, IPI rates were raised by 10% in 1992. Thus, the new variation spectrum was between 10% and 50% with mean and modal values equal to 24.3% and 22%. This was a compensation measure introduced by the federal government to protect the MFZ. Opening of the

[22] Law-Decree 1,435/75.

[23] These rates are applied on similar goods (substitute or perfect substitute for the ones produced in the MFZ) imported or produced elsewhere in the country.

economy implied a decrease in import tax. Thus, this modification might have made IPI more important relative to II.

Import Tax (II)

Imported inputs or goods are totally or partially exempt from import tax. Total exemption occurs in two cases. One is when inputs and products are imported to be used in the MFZ and western Amazonia according to Law-Decree 288/67. The other is when the destination of the final goods using the imported inputs is the western Amazonia. If the destination is the rest of the country then the exemption is partial. The degree of exemption in the latter case was established by a factor of reduction applied to the II rate. This factor varied directly with the value of labor and national inputs, and inversely with the value of imported inputs. As mentioned before, the nationalization factor was effective in 1978. The law defining the coefficient also allowed periodical review of goods and sectors benefited[24], in order to consider changes in capacity of production of the industries located in western Amazonia.

A new reduction factor was defined in 1985. The main characteristic of the new index was the incorporation of weights associated with local, regional and national inputs. The objective was to increase the share of regional value in the final goods. From 1990 on, II rates started to be reduced. On December of 1991 a reduction factor of 88% for goods industrialized in the MFZ was established. This new reduction factor associated

[24] Law-Decree 1435 of 12/16/75.

with decreasing import rates might have had significant impact on the power of this incentive. The extinction of the minimum index of nationalization in 1991 and adoption of the BPP were attempts to maintain the fiscal protection for some industrial sectors of the MFZ. It is worth mentioning that by this time other changes were undertaken. For example, at the federal level there was a 10% increase on IPI for goods with higher weight on the MFZ revenue, and II rates for industries located in the MFZ were reduced.

CHAPTER 4

THE CONCEPTUAL MODEL

This chapter describes the hypotheses to be tested and the economic behavioral model. The hypotheses are presented in two simple statements followed by a discussion about each. The proposed model describes a dynamic situation in which tax incentives and natural resources play major role.

Hypotheses

The two hypotheses that will be examined in this study are the following:

1. There is a positive relationship between fiscal incentives and the Amazonas State economic growth; and
2. There is a negative association between the Amazonas State economic growth and the increase in Amazonas deforested area.

The first working hypothesis states that tax incentives were the primary reason for economic growth in Amazonas State. Before the establishment of the Manaus Free Zone (MFZ), Amazonas suffered from economic stagnation. Prior to the free zone, the industrial production of the State was based on some intermediate products (from

petroleum refinement) and non-durable goods (textile products from *juta*[25]). The policy fueled the economy of the State. Production of durable goods (e.g.; electronics, motorcycles, and watches) to substitute imports was prioritized. Some large companies operating elsewhere in the country and even in other countries found comparative advantages in relocating their plants to Manaus. The free zone generated employment opportunities for local (mostly unskilled) labor and contributed to improve the State's gross domestic product (GDP).

Three arguments shall support the second hypothesis. The first concerns the demographical redesign of the State and its implication to the economic system. The second considers the improvement in the State's income level, and the third looks at the way inputs were combined in the transformation process.

The MFZ was idealized to be a source of economic development and to contribute to colonization of western Amazonia. The free zone also played important role in the demographical rearrangement of the State. Following the Brazilian pattern, the State population was increasing over the last three decades. Both rural and urban populations increased between census observations. The percentage change in rural population was decreasing while urban population was increasing. In 1960, the number of rural residents corresponded to 67.1% of the State's population. In 1991 rural residents dropped to 28.5%. The demographical density of the State increased from 0.45 inh/Km^2 to 1.33 inh/Km^2 between the latter two census observations. That is, the demographical density increased by almost 200%.

[25] Juta is a natural fiber.

The driving factor behind the demographical redesign was the improvement in the level of income. The free zone attracted people from inner areas of the State and from elsewhere in the country[26]. People living in the State's more depressed areas moved to urban centers on their way to larger cities. Data show that municipalities around Manaus were the ones presenting higher urban growth. Thus, when people decided to move to areas offering higher opportunities to improve their utility (better wages, health care, schools, quality of life, etc.) they opted for urban destination. The opportunity cost to stay in their original place was high. Although the policy indirectly contemplated some incentives for activities in the primary sector, these benefits were not accessible to ordinary local citizens. Rural activities were losing attractiveness and the migratory movement towards Manaus as well as to nearby cities increased. Agricultural activities were inferior goods. Consequently, increasing economic growth drove people out of rural areas and activities that minimized the pressure on alternative use of land and other natural resources[27].

The improvement in the power of purchase happened because of the increasing wage mass proportionate by the new industries. The free zone brought a number of new firms that paid higher wages than ever before and promoted the development of local markets throughout urban concentration. At the same time, the policy also facilitated imports of processed food. Fresh meat, poultry, vegetables and exotic fruits were also

[26] Out-of-state immigration is not going to be modeled in this study. It is not an irrelevant variable but it can be left out because most migration to Amazonas in the last three decades were toward the main urban centers like Manaus, Itacoatiara, Manacapuru, Rio Preto da Eva, Presidente Figueiredo, and Parintins. Thus, this migration affected deforestation mostly indirectly through the increase in urban demand for forest goods than directly through activities like slash-and-burn (see section about demographic changes in

imported. Martelli (1969, p.18) describes a good example of these facts:

> I was present when two *caboclos*[28] were trying to sell chickens for a household and the buyer said: 'Why I am going to pay this price for this chicken when I can pay 10.00 for a big duck at the supermarket?' Booth Lines, a British company, ran a supermarket in Manaus where was possible to buy all kinds of food imported from England.

Martelli says that the price level for appliances and food dropped by 30% to 40% as compared to those charged in São Paulo and Rio de Janeiro[29]. Thus, higher purchase power contributed to lessen pressure on food production through food imports.

The third argument supporting the second hypothesis is related to how industries selected their inputs. There are two main criticisms about the MFZ. One is related to efficiency and the other is about the failure of industries in achieving some of the policy main goals. Some efficiency aspects will be modeled in the next section, while the second point is discussed next. The discussion adds information for the understanding of the hypothesis under appreciation.

Industries operating under the benefits of fiscal incentives were supposed to promote economic development and to induce the use of regional inputs combined with national and international inputs. It was expected that the demand for the regional component would stimulate its local production (or extraction) and industrial

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Chapter2).

[27] Unsustainable rural activities are pointed as the main cause of environmental degradation in Amazonia.

[28] It is how a native from Amazonas is called.

[29] See Martelli (1969) for more evidence support.

transformation. This stimulus would lead to discovery of new products from the forest as well as diversification of their industrial use. Research could have been undertaken for this sake. This process would be capable of consolidating the program and promoting economic growth.

The planned situation was not consistent with the facts. Industries used fiscal benefits to import their inputs. The electronic sector, the largest, never-used Amazonian precious woods to make TV cabinets. The wristwatch sector never used leather from Amazonian's fish skin for watchbands and the packing material sector, which used of trees to make paperboards, was weakly implemented. According to Veja (1997), the Manaus Free Zone is an economic failure and contributed to double the population of Manaus, which concentrates half of the State population, and to increase poverty. Thus, economic growth in Amazonas only has a tenuous connection with the use of regional natural resources and local development.

In summary, the tax incentive policy improved the State's economy and induced continuous increase in its urban population and favored import of industrial inputs. Urban opportunities made rural activities relatively more expensive and inferior. Resources were diverted from the latter, lessening the pressure on alternative uses of some natural resources. Higher wages and policy benefits made imported food relatively cheap. This contributed even more to lessen the pressures on local food production and use of some natural resources. Given the available technology, to use land for commercial food production was expensive. Finally, industrial activity increased labor demand and failed to use regional natural resources.

The hypotheses descriptions presented above can be expressed in a simplified mathematical relationship where human behavior is attempted to be modeled. Thus, the next section develops the behavioral model. The model is a modified approach of the work of Kahn and McDonald (1995).

The Behavioral Model

When there are fixed or lumpy investments in infrastructure or plants and equipment and continuous changes in the stock of environmental and natural resources, a decision made will have cumulative effects over time. In these cases, the social planner faces an intertemporal planning problem. A dynamic problem poses the question of what is the optimal magnitude of a choice variable at each point in time over a given time interval.

Idealistically, the social planner would desire the maximization of social welfare through the consumption of marketed goods and services and ecological services. However, the actual objective was to maximize the stream of consumption of goods and services from time $t = 0$ to T for all municipalities m. In addition, consumption is also considered instead of welfare because environmentalism in Amazonas did not begin until the 1990s. This means that the social planner perceived the environment as an important supplier of raw materials that could be used to satisfy consumption needs and disregarded the environmental implications of the use of such materials. The social planner is represented by an amalgam of the state and national governments.

The maximization problem is given by

$$\underset{N,\delta}{Max} \sum_{i=1}^{m} \int_{t=0}^{T} [C_i(t) - Z_i(\delta)] e^{-rt} dt . \qquad (1)$$

The function states that maximization is given by the present value of the stream of consumption minus the cost to the rest of the country of the economic incentives, δ. This cost can be thought as plants leaving their original places or school and health care not provided by the federal government in other parts of the country. The social planner has the option to choose the level of economic incentives and the amount of natural resources, N, which can be used to produce consumption. Table 6 defines the variables used in this model.

Table 6 - Definition of variables

Variables	***Definition***
Y	Output of the economy
C	Consumption
I	Private investment
G	Government consumption
X	Net exports
K	Stock of physical and human capital
N	Use of extractive natural resources, which includes water, air, and soil quality, biodiversity, forested land, fisheries, and mineral resources.
L	Stock of labor
S	Stock of forested area
Z	Social cost of economic incentives
r	Discount rate
δ	Average percentual of economic incentives
λ_K	Shadow price of a unit of capital
λ_S	Shadow price of a unit of forest resources
θ	Lagrange multiplier

The planner is subjected to investment and to the rate of extraction of natural resources, more specifically deforestation. These two elements determine the state equations of the problem given by Equations 2 and 3. The problem also presents a constraint with respect to the level of economic incentives. Fiscal incentives granted to firms to relocate to the MFZ were a powerful mechanism that induced firms to overcome natural obstacles, namely, distance and isolation from national markets. Firms would not have moved to the State if incentives were not substantial to compensate relocation and operation of the industrial process. Thus, the planner faced the constraint of maintaining a minimum level of economic incentives without which firms would stop their production and the whole policy would succumb. This constraint is shown by expression 4.

$$\dot{k}_i = \alpha_0 + \alpha_1 \delta K_i - \alpha_2 K_i \tag{2}$$

$$\dot{s}_i = -N_i \tag{3}$$

$$\delta \geq \bar{\delta} \tag{4}$$

State Equation 2 shows that investment depends on three factors: a constant α_0, plus the beneficial effects of economic incentives and other positive factors captured by α_1 minus all factors negatively related to investment such as interest rates and

depreciation. These negative factors are captured by α_2. Equation 3 indicates that as more natural resources are used by the economy, more deforestation takes place[30]. Expression 4 describes the constraint faced by the social planner. That is, the level of economic incentives must be greater or equal than a given level $\overline{\delta}$.

The economy of the State is represented by the macroeconomic identity 5, which shows that the total aggregate income is Y plus economic incentives, δY. Economic incentives represent a transfer from to rest of the country to the State and, by definition, they are a fraction of Y. Income is allocated among consumption, investment, government consumption and net exports, C, I, G and X respectively.

$$Y(t) + \delta Y(t) = C(t) + I(t) + G(t) + X(t). \tag{5}$$

From Equation 5 it is possible to find the identity for consumption. This is shown by equation 6.

$$C(t) = (1+\delta)Y(t) - I(t) - G(t) - X(t). \tag{6}$$

[30] Many times throughout the text the term 'natural resource' will be used to mean deforestation. The reader should keep in mind that this is possible according to Equation 3. More use of natural resources implies in a decrease in forested area.

The output of the economy is modeled using two different functional forms. One is a Cobb-Douglas function while the other is a quadratic formulation. This is done to broaden the analysis and to have better understanding on how the choice of a specific functional form can affect the results. This is also done because the Cobb-Douglas specification means that if one of the inputs is not used the output will be zero. This may not be realistic. For example, the production can happen without local natural resources N. The production functions have four inputs. Capital and labor are traditional. Capital represents human and physical capital. The other two are natural resources N, and forested land S. The forest sector is not explicitly modeled in the production functions but it is taken into account through the level of natural resources and forested land. For more discussion on how sustainable and unsustainable forest activities are taken into account refer, to Kahn and McDonald (1995).

The maximum principle is derived from the modified Hamiltonian functional 7 where subscripts are dropped. The modification is due to the constraint on economic incentives. The functional represents the overall consumption prospect at any point in a given time frame. The problem is first solved for the Cobb-Douglas specification.

$$H = [(1+\delta)\beta_0 K(t)^{\beta_1} N(t)^{\beta_2} L(t)^{\beta_3} S(t)^{\beta_4} - \alpha_0 - \alpha_1 \delta K(t) + \alpha_2 K(t) - G(t) - X(t) - Z(\delta)]e^{-rt}$$

$$+ \lambda_K [\alpha_0 + \alpha_1 \delta K(t) - \alpha_2 K(t)] - \lambda_S [N(t)] + \theta[\overline{\delta} - \delta]. \qquad (7)$$

The first term of the functional is the consumption function at time t, based on the output of the economy and its inputs as well as on the other consumption alternatives, namely, investment, and government expenditures and net exports. The cost of economic incentives to the rest of the country subtracts from consumption. The first term represents the present consumption corresponding to policies N and δ. The second and third components to the right of 7 represent the rate of change in the value of capital accumulation and deforestation, respectively. They become monetary values when multiplied by their respective shadow prices λ_K and λ_S. Differently from the first term, the latter two terms are related to future effects of N and δ. Thus, the Hamiltonian captures the overall consumption prospect of the policy decisions with both present and future effects taken into account.

The fourth term to the right of 7 includes the constraint faced by the social planner. The Lagrangian multiplier θ multiplies the constraint equation. The purpose of the expression is to incorporate the constraint when it is binding, that is $\theta > 0$ and $\delta = \overline{\delta}$. When the constraint is not binding ($\theta = 0$) the functional works normally and H is a pure Hamiltonian.

First Order Conditions and Discussion of Modeling

The first order conditions for Equations 8 and 9 present the state variables with time parameters eliminated for simplicity. They indicate the optimal choice of the policy

variables δ and N. Interior solutions are assumed to exist and 10 and 11 show the co-state equations.

$$\partial L/\partial \delta = (\beta_0 K^{\beta_1} N^{\beta_2} L^{\beta_3} S^{\beta_4} - \alpha_1 K - Z_\delta)e^{-rt} + \alpha_1 \lambda_K K - \theta = 0. \quad (8)$$

Expression 8 can be rewritten as

$$\beta_0 K^{\beta_1} N^{\beta_2} L^{\beta_3} S^{\beta_4} = (\alpha_1 K + Z_\delta) - (\alpha_1 \lambda_K K - \theta)e^{rt}. \quad (8')$$

The first order with respect to N is

$$\partial L/\partial N = \tfrac{(1+\delta)\beta_2}{\lambda_S}(\beta_0 K^{\beta_1} N^{\beta_2} L^{\beta_3} S^{\beta_4})e^{-rt} - \lambda_S = 0 \quad (9)$$

and the co-state equations are

$$\dot{\lambda}_K = -\partial L/\partial K = \beta_2(1+\delta)(\beta_0 K^{\beta_1 - 1} N^{\beta_2} L^{\beta_3} S^{\beta_4})e^{-rt} + (\delta\alpha_1 - \alpha_2)(\lambda_K - e^{-rt}) \quad (10)$$

$$\lambda_S = -\partial L/\partial S = \beta_4(1+\delta)(\beta_0 K^{\beta_1} N^{\beta_2} L^{\beta_3} S^{\beta_4 - 1})e^{-rt} \quad (11)$$

$$\partial L/\partial \theta = \bar{\delta} - \delta \geq 0 \qquad 6 \geq 0 \qquad 6\,\partial L/\partial 6 = 0. \quad (12)$$

Equation 12 shows the Kuhn-Tucker condition. The first term simply restates the constraint. The third term is the complementary-slackness condition and ensures that the constraint will vanish in the solution.

To determine an expression for natural resources, equation 8' is plugged in 9. The resulting equation is given by:

$$N = \frac{(1+\delta)}{\lambda_S}\beta_2\left[(\alpha_1 K + Z_\delta)e^{-\pi} - (\alpha_1\lambda_K K - \theta)\right]. \qquad (13)$$

The optimal level of use of natural resources, and consequently deforestation, is an explicit function of economic incentives (δ), the stock of capital (K), the marginal cost of economic incentives to the rest of the country (Z_δ), and shadow prices of the forest resources and capital. The expression implicitly considers the other inputs of the economy through the shadow price of capital and forest resources. The equation is also a function of the coefficient α_1.

The first term in Equation 13 is positive. Economic incentives are always positive. If they are negative they are taxes and will be conflicting with the objective of the policy. The shadow value of forest resources has to be positive because *ceteris paribus,* increasing the size of the forest will increase output. The coefficient of natural resources in the production function β_2 is also positive. The first term between brackets is also positive because all of its components are positive. α_1 is the term capturing all factors

affecting investment positively and Z_δ is the marginal social cost for the rest of the country, which is assumed to be positive. The last term in 13 is likely to be positive. The product among the coefficient α_I, the shadow price and stock of capital is positive. This term is positive because even if the constraint θ is strong enough is not likely to exceed the product among the other elements of the term. If economic incentives are not strong enough to promote the economic activity, all terms in the expression will decrease in magnitude. The sign of the expression will depend on the absolute size of the terms between brackets. The analysis suggests that N will be positively related with the right hand side because the first term is likely to be larger than the second.

When the solution is unconstrained ($\theta = 0$) and all terms multiplying θ disappear, this will not result in big changes relatively to the constrained case because the last term in 13 is still positive and less than the first term between the brackets.

Equation 13 shows that economic incentives are the mechanism used by the government to induce firms to locate in the MFZ. Economic incentives and the stock of capital move in the same direction because more economic incentives imply more capital K. More economic incentives lead to direct increase in the use of natural resources. The stock of capital affects N in a directly proportional manner. Differently from economic incentives, the stock of capital also contributes to outweigh its positive effect with respect to the use of natural resources. It is also interesting to note that the higher the cost of the policy to the rest of the country, the larger is its effect on deforestation.

Next, the quadratic formulation of the production function is worked for the same setup presented in 1-4. Natural resources are the interaction factor and the function is presented in equation 14:

$$Y = \beta_0 + \beta_1 K + \beta_2 N + \beta_3 L + \beta_4 S + \beta_5 K^2 + \beta_6 N^2 + \beta_7 L^2 + \beta_8 S^2$$

$$+ \beta_9 NK + \beta_{10} NL + \beta_{11} NS \,. \qquad (14)$$

The first order conditions are

$$\partial L/\partial \delta = [(\beta_0 + \beta_1 K + \beta_2 N + \beta_3 L + \beta_4 S + \beta_5 K^2 + \beta_6 N^2 + \beta_7 L^2 + \beta_8 S^2$$

$$+ \beta_9 NK + \beta_{10} NL + \beta_{11} NS) - \alpha_1 K - Z_\delta]e^{-rt} + \lambda_K \alpha_1 K - \theta = 0 \,. \qquad (15)$$

Equation 15 can be rewritten to give

$$(\beta_2 + \beta_6 N + \beta_9 N + \beta_{10} L + \beta_{11} S) = \frac{(\theta e^{-rt} - \alpha_1 \lambda_K K e^{rt} + \alpha_1 K + Z_\delta - A)}{N} - \beta_2 N \qquad (15')$$

where

$$A = (\beta_0 + \beta_1 K + \beta_3 L + \beta_4 S + \beta_5 S^2 + \beta_7 L^2 + \beta_8 S^2) e^{-rt}.$$

The first order with respect to N is

$$\partial L/\partial N = [(1+\delta)(\beta_2 + 2\beta_6 N + \beta_9 K + \beta_{10} L + \beta_{11} S] e^{-rt} - \lambda_S = 0. \quad (16)$$

The co-state equations are

$$\dot{\lambda}_K = -\partial L/\partial K = \left[(1+\delta)(\beta_1 + 2\beta_5 K + \beta_9 N)\right] e^{-rt} + (\lambda_K - e^{-rt})\alpha_1 + (\lambda_K - e^{-rt})\delta\alpha_2 \quad (17)$$

and

$$\dot{\lambda}_S = -\partial L/\partial S = \left[(1+\delta)(\beta_4 + 2\beta_8 S + \beta_{11} N)\right] e^{-rt}. \quad (18)$$

Rewriting 16 as

$$2(1+\delta)\beta_6 Ne^{-\pi} + (\beta_2 + \beta_9 K + \beta_{10} L + \beta_{11} S)(1+\delta)e^{-\pi} = \lambda_S . \tag{19}$$

and applying 15' in 19 and solving for N yields:

$$N = \frac{1}{(1+\delta)(2\beta_6 - \beta_2)e^{-\pi}} \left(\lambda_S \pm \sqrt{\lambda_S{}^2 - 8(\beta_6 - \beta_2)(1+\delta)^2 e^{-2\pi} B} \right) \tag{20}$$

where

$$B = \alpha_1 K + Z_\delta - A - (\lambda_K \alpha_1 K - \theta)e^{-\pi} .$$

When the quadratic production function is used, the resulting equation for natural resources yields an expression that explicitly takes into account all other inputs. This is the main gain of this specification. That happens through A, which is included in B. Another important information added is that the constraint will have small significance. This is interesting because it suggests that deforestation will heavily depend on how the economy combines its resources. The sign of Equation 20, however, is not determined for two reasons. First, the sign of the first term on its right will depend on the absolute values of the coefficients β_2 and β_6, and the second is because the radical in Equation 20 has both positive and negative roots.

The results of this modeling are summarized in Table 7 and indicate that Equations 13 and 20 provide enough information to support empirical estimation to explain the effect of the Manaus Free Trade Zone on deforestation in the State of Amazonas.

Table 7 – Theoretical expected signs of marginal values of optimal results of factors affecting deforestation

Solution/Production Function	Inputs	Economic Incentives	Social Cost	Competing uses of Y
Unconstrained				
(a)-Cobb-Douglas (K)	(+)	(+)	(+)	zero
(b)-Quadratic (K,L,S)	(+) or (-)	(+) or (-)	(-)	zero
Constrained				
(a)-Cobb-Douglas (K)	(+)	(+)	(+)	zero
(b)-Quadratic (K,L,S)	(+) or (-)	(+) or (-)	(-)	zero

The first main finding of this modeling is related to the constrained and unconstrained solutions. The model shows that a minimum level of economic incentives plays little role on the determination of the sign of the optimal level of natural resources. That is, the signs are going to be the same in both constrained and unconstrained

situations[31]. However, economic incentives do affect the magnitude of *N*. The case is relevant from the policy perspective. If the social planner wants to revise the policy toward a reduction or elimination of economic incentives, this can minimize deforestation caused by incentivized production but can at the same time worsen it by promoting a production shift from one sector of the economy to another. Obviously, the size of this shift will depend on the degree of substitutability among inputs. Optimal level of natural resources may also be associated to no free zone policies and/or the existent stock of capital. The main difference between the constrained and unconstrained situation though seems to be the magnitude of deforestation due to the inclusion or exclusion of the constraint multiplier in Equations 13 and 20. As can be seen from Table 7, the constrained situation mimics the unconstrained and/or vice-versa. Because of this kinship the discussion will proceed based on the unconstrained case.

The model suggests that deforestation takes place due to the way natural resources are combined with other inputs rather than a result of the competing uses of income. Competing uses of aggregate income had zero effect on deforestation. This may not be a very realistic situation because government consumption is explicitly left out of the results and governments are pointed in the Environmental Economics literature as an important source of inefficiency. However, it does not mean that it was not considered implicitly. For example, the coefficient α_I in the private investment equation may well capture government actions like infrastructure investments and human capital formation.

[31] See equations 13 and 20. The constraint multiplier is not likely to exceed the product among α_I and the shadow price and stock of capital.

As far as inputs are concerned, the Cobb-Douglas function shows that only capital directly affects natural resources. On the other hand, the quadratic form indicates that all inputs have a relevant role but the direction of the effect is unknown. This seems to be a theoretical limitation of the method. When the maximum principle is derived it does not take into account indirect effects that the exogenous variable(s) will have on other endogenous variable(s) of the system. It captures only direct effects of a given variable on the endogenous variable. Even though other variables are implicitly modeled through the shadow price of capital, this work will address this problem in the empirical section by explicitly including or excluding other variables believed to be relevant. For example, the unconstrained solution for the Cobb-Douglas specification can consider not only capital but also forest and labor resources as well.

Economic incentives affect natural resources in the same direction that inputs do in both specifications. *Ceteris paribus*, the higher the level of incentives, the more (Cobb-Douglas and quadratic) or less (quadratic) will be the effect on natural resources. This is so because fiscal incentives have the primary objective to induce capital formation and effects on deforestation are related to the degree that capital is combined with other factors of production. The quadratic form seems to capture this process better than the Cobb-Douglas does. For example, with more incentives for one type of input, such as capital, more of that input can be used to the detriment of other input such as natural resources. Introduction of a new input may require research and development and this can be expensive from the perspective of firms. In addition, if the degree of substitution among inputs is high then there is no need to increase the relative participation of the

non-incentivized input(s). If we consider that the term between the parentheses in Equation 20 is smaller in absolute value than the first, the higher level of economic incentives is strong enough to increase or reduce the optimal level of natural resources. This can be an important input for policy because it gives the social planner the instruments to control part of deforestation through non-forest policies. The sign of Equation 19, however, will depend on the way that economic incentives and inputs interact.

The discussion above may also help to understand why in the constrained solution the constraint multiplier has minor importance on the determination of the sign of the optimal level of natural resources. If the level of incentives is very low the economy can shift towards the use of substitute inputs. As an input itself, natural resources use may be driven by the size of the stocks of the other inputs and not only by the minimum level of economic incentives. In this case the constraint is not going to be strong enough to induce significant change. This observation does not conflict with the justification given to introduce the constraint in the problem. That is, if economic incentives are too low then the economy will collapse. Rather, it enriches the analysis in the sense that it adds more reality to the case. For example, reduction of economic incentives can favor extractivism relative to high-tech firms.

The social cost of economic incentives to the rest of the country affects the optimum level of natural resources in different ways depending on the functional form of the production function. It is not a surprise. The economic literature about economic incentives also deals with the same type of conflict. In general lines, critics argue that

subsidies introduce inefficiency in the economy while defenders say that inefficiencies are balanced or even outweighed by equity gains.

In ideal terms, all variables in Equations 13 and 20 would be included in the empirical analysis. However, data limitation does not permit that. For example, the technical coefficients of the production functions are not available. This may not be a big problem in this case because the study is considering a closed system, the economy of one given state in Brazil. Because subsistence production is not modeled, it is likely that all areas face a relative homogenous production function. Data measuring human and physical capital directly are not available either. Net exports will be excluded because there are no data available for this variable. The most serious empirical problem though can be data for fiscal incentives. There are a number of economic incentives available for firms operating in the MFZ but very little systematized records for lost fiscal revenues or incentives indexes. This problem will be addressed by the creation of an interactive variable based on two types of federal economics incentives. Finally, environmental as well as time invariant variables like distance will be included in an attempt to control for non-economic factors affecting the performance of the economy and, consequently, deforestation.

CHAPTER 5

ECONOMIC INCENTIVES AND GROWTH

The first hypothesis presented in Chapter 4 states that economic incentives were responsible for the economic growth that took place in the Amazonas State during the last three decades. This chapter presents a more detailed explanation of the recent evolution of the economy of the Brazilian North region in an attempt to theoretically explain that hypothesis. No empirical model will be used for this purpose. The explanation will rely on comparison of economic performance among the states of the region. The region currently has seven states: Amazonas, Pará, Acre, Roraima, Rondônia, Amapá and Tocantins. The first section deals with the regional historical economic background of the states. The second section talks about the region's economic performance, and finally, the third section goes over some efficiency aspects related to the Manaus Free Zone. Even though the first and second sections are developed based on the analysis of the Brazilian North Region, the focus will remain on the Amazonas State.

The Regional Economy

The economic development of the Brazilian North region has been marked by strong government intervention. According to Bahiana (1991), from the mid-sixties on one of the most common government options to attract investors to the region was the

concession of economic benefits to firms locating in the region. These benefits allowed firms from center-southern Brazil to invest in export- or import-oriented activities like high-tech industries, mining, agricultural and cattle-raising activities.

These economic incentives were part of a bigger plan named *Operação Amazônia* that started in the late sixties. The plan relied heavily on the construction of a highway system to link the region to the rest of the country. Following this highway plan there was a colonization plan that aimed at the establishment of agri-cities—villages with no more than fifty families— and an *agrópolis*—a city surrounded by twenty agri-cities. The most successful results of those plans happened in the Pará and Rondônia States.

The first export-oriented projects receiving support from the federal government were those for cattle raising and agriculture. These projects received subsidies from the Superintendence for the Development of Amazonia (SUDAM) and were initially given to big multi-national companies like Volkswagen (Germany), Suiá-Missu (Italy), Bruynzeel (Holland) and the Jari Florestal e Agropecuária (USA). Paiva *et al.* (1991) state that during the seventies 79.12% of the projects receiving federal economic incentives were for cattle raising and most of them were located in southeastern Pará. Except for Pará and Rondônia, other states of the region received relatively few incentives for cattle raising and agricultural activities.

The mining industry was also a very important component of the export-oriented package of economic incentives for the region. Among the mining projects was the *Grande Carajás*, initially a Brazilian/USA holding. Carajás was a giant iron-mining project. Two other large mining projects were Jari and Trombetas. Jari was a multi-

purpose project involving mining, agriculture, forestry and cattle raising. Trombetas was a bauxite-mining project that started in 1971. All these projects were located in Pará and received massive government incentives because of their potential to increase the national exports and to contribute to the payment of Brazil's external debt. Two other mining projects relevant for the mining industry in the region and also receiving government incentives were the exploitation of manganese in Amapá and bauxite in Rondônia.

The only import-oriented program in the region was the Manaus Free Zone in the Amazonas State, which was a duty-free port where high-tech industrial production was promoted through economic incentives. The Free Zone allowed the establishment of assembling plants of multinational industries to locate in Amazonas and export to the rest of the country.

Table 8 was constructed to summarize and give a visual representation of the geographical distribution and emphasis of different government incentivized activities in the North Region. The table is not a precise indication of the different economic incentives that were used to promote development, nor does it cover all types and kinds of subsidies and economic activities. Its objective is to give a better representation of the main programs and projects that were developed during the seventies and eighties in that part of Brazil.

Table 8 – Emphasis given to general categories of government incentivized activities in the Brazilian North Region during the seventies and eighties

State	Colonization	Agriculture/Cattle Raising/Forestry	Mining Industry	Import-oriented Industry
Acre	1	1	1	1
Amapá	1	1	2	1
Amazonas	1	1	1	3
Pará	3	3	3	1
Rondônia	3	3	2	1
Roraima	1	1	1	1

Low/none = 1, Medium = 2, High = 3.

As can be seen from the table, the states of Acre and Roraima were the ones receiving relatively few government/economic incentives. The main economic activities undertaken in Acre were cattle raising and extractivism and there were no direct or specific incentives for the State. Roraima also had a similar situation. The economy of the State during that period was mainly concentrated on diamond and gold mining. Gold was a by-product of the diamond mining. The direct incentives benefiting Amapá were mostly related to the manganese mining industry. Even though some industrial diversification had been tried in Amapá, the manganese industry remained as the most important.

Pará and Rondônia were the states receiving more incentives from the part of the Brazilian government. This was so because of their highway network which helped the colonization programs and the Brazilian need to export. The colonization programs concentrated along the Belém-Brasília highway, more specifically in south Pará and

Rondônia. Notice that the weight given to the mining industry in Rondônia is related to cassiterite (tinstone) mining. Amazonas was the only state receiving direct incentives for the import-oriented industry. The State had received negligible benefits from other policies.

Economic Performance

To understand how economic incentives affected the economic growth throughout the region and in particular in the Amazonas State, it is important to look at some economic indicator of performance. One frequently-used indicator is the GDP. Table 9 shows the share of each state of the region in the Brazilian GDP (see Appendix 2 for table with raw data). Table 9 gives the values for six states of the region[32].

Observe that the share of North Region's GDP was increasing over the period and that its participation in the national economy was relatively low. The shares of Acre, Amapá, Roraima and Rondônia were the ones with overall relative low values. Amazonas and Pará had the highest share in the region's GDP in every year. Both states showed an increasing trend for their gross domestic products. Amazonas' GDP was always smaller than Pará's. The difference between the states' share was higher in 1970. From 1975 on Amazonas started to approach Pará and their values were almost the same for 1985, 1990 and 1995.

[32] The State of Tocantins was left out because its was created in the late 80s and there is not enough data about it. Tocantins was the former northern portion of Goiás State.

Table 9 – North Region's states share in the Brazilian GDP from 1970 to 1995

State	1970	1975	1980	1985	1990	1995
Acre	0.13	0.08	0.12	0.14	0.15	0.14
Amapá	0.11	0.06	0.07	0.08	0.09	0.09
Amazonas	0.69	0.75	1.09	1.21	1.4	1.3
Pará	1.1	1.05	1.65	1.29	1.45	1.32
Rondônia	0.1	0.12	0.23	0.25	0.31	0.29
Roraima	0.02	0.03	0.04	0.06	0.09	0.14
North Region	2.15	2.11	3.2	3.05	3.48	3.54
Brazil	100	100	100	100	100	100

Source: FGV (1996).

Another way to look at economic performance is through the per capita GDP. Table 10 shows the evolution of the per capita GDP for the region, with 1970 as the base year (see Appendix 3 for table with raw data).

All states showed increases in per capita income. Amapá and Rondônia had a relatively low increase in their incomes. In twenty-five years the growth in their per capita GDP was not superior or close to the regional growth. Acre and Pará were around the regional but below the national rate growth of per capita GDP. Amazonas and Roraima were the only two states presenting growth of GDP per capita superior to both the regional and national growth. Throughout the period, Roraima had the highest growth.

Table 10 – Growth of the North Region's per capita GDP from 1970 to 1995, 1970=100

State	1970	1975	1980	1985	1990	1995
Acre	100	169	463	667	692	734
Amapá	100	140	290	364	361	385
Amazonas	100	286	747	976	1050	1084
Pará	100	245	675	609	625	625
Rondônia	100	179	355	369	336	297
Roraima	100	431	851	1062	1065	1471
North Region	100	246	645	669	648	687
Brazil	100	283	552	705	721	853

Source: Appendix 3.

Looking at Tables 9 and 10 it is possible to infer that the Manaus Free Zone did have an important contribution for the regional economic performance and consequently to the State of Amazonas. The data showed in Table 8 indicate that the shares of the Amazonas State and North Region in the 1970 Brazilian GDP were 0.69% and 2.1%, respectively. In 1995, they increased to 1.3% and 3.5%. At a first glance, these numbers may not show relevant economic growth. However, if one looks at Table 9, the conclusion changes. Taking 1970 as the reference year, the 1995 State per capita GPD increased by 1,084% while the national and regional increment reached 853% and 687%, respectively. Thus, even comparing the Free Zone to the large impact (both economic and environmental) export-oriented projects, the policy demonstrated that the FZ's contribution was very important to increase both the Amazonas and region's economic growth over the last two and a half decades. The Free Zone policy, however, was not

carried out without a cost. One component of this cost will be considered next.

Some Efficiency Considerations

This section briefly reviews one aspect related to the economic cost of the Free Zone policy, that is, its fiscal cost. The analysis is not going to consider the issue in depth because of data constraints (see footnote 38). The period under review is the one between 1990 and 1994. For this period there is reasonable information for total federal tax revenue and lost tax revenue for both import (II) and industrialized goods (IPI) taxes.

Despite the geopolitical and economic benefits brought by the Manaus Free Zone, the policy has been heavily criticized on its efficiency grounds. Critics argue that the Free Zone is expensive for the country and has contributed very little to enhance the value of the national product. Critics also argue that the treatment given to the Free Zone discriminates against other firms located in central-southern Brazil and contributes to avoid the development of market economies. The policy has also been criticized because of its impact on the urban quality of life in some cities of Amazonas and in particular, Manaus. This latter aspect is not going to be analyzed in this study.

As explained in Chapter 3, economic incentives for the Free Zone existed in a variety of forms and they also existed at different government levels. Such diversification and complexity associated with lack of data make analyses very difficult. To partially circumvent this problem and extract some useful information from the available data, only economic incentives associated with the import and industrialized goods tax will be

considered here (see Chapter 3). Table 11 gives the total federal revenue and the estimated lost revenue from the import and industrialized goods tax.

Table 11 – Total federal revenue and estimated lost revenue for import and industrialization tax in Amazonas between 1990 and 1991, in US $ 1,000

Year	Total federal tax Revenue [a] (A)	Estimated lost federal Tax revenue from II and IPI [b] (B)	(A) – (B)
1990	405,719	1,383,956	-978,237
1991	307,361	904,176	-596,815
1992	204,278	659,856	-455,578
1993	282,090	1,458,576	-1,176,486
1994	414,173	1,846,110	-1,431,937

Source: (a) Benchimol (1995), (b) SUFRAMA (see appendix 4).

The column (A) of the table shows that the total federal tax revenue oscillated substantially between 1990 and 1994. During this period the State economy lived a severe recession due to macroeconomic policies. However, Benchimol (1995) states that the total federal tax revenue during the period in Amazonas represented 49.44% of the region's federal revenue. Pará came in second place with 29.58%. Column (B) shows estimates for lost federal revenue from the import and industrialized goods tax. Observe that lost revenues also had the same pattern of oscillation that revenues had. The third column gives the difference between columns (A) and (B). Notice that even considering

all federal taxes, column (A) is kept considerably smaller relative to column (B). The fourth column shows the net fiscal benefit of the policy.

Even thought the net fiscal balance of the policy is negative it is not safe to draw a conclusion about whether the policy is worthy or not based only on those values. It is important to recall that the contribution of the economy of the State in terms of GDP for the rest of the country is relatively low and so can be the net fiscal benefits. However, the table clearly shows that the Amazonas is very dependent on economic incentives. From the perspective of the Amazonas' planner this can be an important piece of information. If the planner looks at the economic theory he or she is going to see that such a high (from the perspective of the State) level of economic incentives can harm the sustainability of the economy in the long run if market economies are pursued. Thus, based on this brief efficiency discussion, one can infer that the policy may need to be reviewed with respect to its overall impact on the entire Brazilian society.

CHAPTER 6

THE DATA AND ECONOMETRIC METHOD

This chapter will describe the data sources, definitions of the variables and the econometric method to be used. The explanations will be divided in two sections. The first section talks about the data sources and gives a detailed explanation about the variables and the second section describes the econometric method to be used in the estimations.

The Data

The complete data set available used in this work came from different sources. Data on economic, demographic, agricultural and ecological variables were from the *Instituto de Pesquisa Econômica e Aplicada*'s database (IPEA, 1996) collected for the years 1980 and 1985 for all municipalities in the State of Amazonas. For a more comprehensive description of this data set see the Amazon Report by Andersen *et al* (1996). The other data source was the Amazonas Statistics Yearbook (Governo do Amazonas). Data from the Yearbook included electrical energy consumption and secondary education. Industrial electricity consumption was used to approximate the stock of physical capital while enrollment in secondary school was used to approximate human capital.

The study focuses on the economies of the municipalities in the Amazonas State between 1980 and 1985. As of 1985 the State of Amazonas had sixty-two municipalities but the actual sample used in the regressions is reduced to thirty-four units. This is done for two main reasons. One is that as we go back in time, the data are incomplete for some relevant explanatory variables, and the other is because many municipalities were created between 1980 and 1985. Estimation using all sixty-two units would introduce bias in the model because of exaggerated lack of data for these units. Based on these problems two actions were taken. First, all missing observations for the dependent variable were dropped. This reduced the sample to forty-four cross-sectional units. Finally, all missing observations for the explanatory variables were dropped. A list of the municipalities used in the estimations is found in the Appendix.

Ideally, all variables suggested by the theoretical model should be included in the regression. However, due to data limitations, some had to be approximated. The mathematical results presented by Equations 13 and 20 in Chapter 4 indicate two relationships between the use of natural resources and other factors of the economy of the State. The model also defines in Equation 3 that as more natural resources are used by the economy, there is a greater increase in deforestation. Satellite data on deforestation in Amazonia became available by the mid-seventies. These data, however, were aggregate by state and suffered from a lack of continuity. For example, the web site of the Brazilian Space Agency (INPE, 1998) publishes the deforested area in Amazonia starting in 1978. From this point on there is an eight-year gap that goes until 1988. This was considered as a heavy period of deforestation in Amazonia.

Because of the problems associated with satellite data and the requirement for more disaggregation, this study will follow Skole *et al* (1994, p. 319).

> It is possible to obtain deforestation estimates using tabular summaries from standard government census sources... These data do not directly report the area deforested, but instead they provide estimates of land in various forms of permanent and temporary agriculture, including pastures. Because the major cause of deforestation in the Amazon is agricultural expansion, these data can be used as a proxy for deforestation, but they cannot provide a direct measure of deforestation as with remote sensing.

Thus, agricultural census data are used to approximate deforestation. The variable is determined by the sum of the private area used for temporary and permanent crops, planted pasture and fallow land in Amazonas. It is assumed here that public lands are not deforested. This is a reasonable assumption in the Brazilian Amazonia scenario, particularly in the State of Amazonas. The model is estimated for 1985, but it also includes information from the previous census period, that is, 1980. The dependent variable $\Delta D8580$ is then constructed by the difference of deforestation between 1985 and 1980 for each cross-sectional unit.

Even though not explicitly shown in the theoretical model, past deforestation is also believed to affect changes in deforestation. In that model old deforestation is indirectly introduced through the remaining stock in forested area, S for each year.(see Chapter 4). The variable used to incorporate this past information in the empirical model is *DEF80*.

Table 12 – Definition of variables for the empirical model

Variable	Unit	Definition
ΔD8580	Km^2	Change in deforested area between 1985 and 1980. Deforestation is approximated by the sum of annual and perennial crops, planted pasture, and fallow land.
DEF80	Km^2	Stock of deforested area for 1980. Deforestation is approximated by the sum of annual and perennial crops, planted pasture, and fallow land.
ΔGDP	1985 cruzeiros	Change in real Gross Domestic Product between 1980 and 1975.
ROADD	Km/ Km^2	Road density. It is a proxy for government consumption.
CAP	KWh	Industrial electricity consumption. It is a proxy for the stock of physical capital.
SEC	Students	The number of students enrolled in secondary school. It is a proxy for human capital.

Two forms of capital are used: physical and human capital. Physical capital is thought of as machines, buildings and other equipment used for production. Human capital is the stock of skilled workers. Data for physical capital in the MFZ are not available. A common way to handle this problem is to use the consumption of electrical energy as a proxy. Energy consumption is believed to proxy the stock of physical capital. This study uses the industrial consumption of electrical energy, which is measured in kWh to approximate the variable and is denoted by *CAP*. This variable is expected to be negatively related to the change in deforestation.

Human capital alters the quality of the labor force and consequently production. An alternative to measure this capital is through primary and secondary schooling. De Paula (1996) discusses the reasons why both primary and secondary schools are

considered reasonable approximations for human capital. The author's bases his argument in the theory of economic development and growth. The proxy is constructed as the ratio of total students enrolled in primary/secondary education to the number of individuals of primary/secondary-school age (6-11 years). Wood and Kersti (1997) and Owens and Wood (1997) develop another approach to assess to role of human capital in development. Both develop an analysis about the role of skilled labor and natural resources in exported-oriented industrialization. The main point developed by the authors is whether or not differences in the ratio skill to natural resources affects the way economic development is achieved and maintained. Their variable is constructed based on the ratio skill/land. Skill is measured by average years of schooling and land is measured by area.

The MFZ is a program that stimulated the relocation of capital intensive firms to Amazonas. Such firms, in principle, would increasingly require skilled workers to handle industrial tasks and to develop new products and processes based on regional inputs. More development would require more skilled workers. New products derived from local natural resources would be created and economic growth would be associated with more human capital and more use of natural resources.

This study uses the variable *SEC* to proxy human capital. *SEC* is the number of students enrolled in secondary school in each municipality. Unfortunately, human capital could not be used as suggested by previous studies. One empirical problem related to the approach used in this study is that it considers human capital as exogenously determined. Human capital is a variable that depends on a number of factors (e.g.: income, sanitary

conditions, health care, etc.). Another problem with this variable is that it does not consider any other information such as age or the working force structure. Data are not available to include these elements in the estimation. Because of the way secondary school is being used, *SEC* can be either positively or negatively related to the change in deforestation.

Equations 13 and 20 do not explicitly consider government consumption, but this study attempts to model it. Government plays a major role in the Amazonas economy. For the MFZ to become operational, public infrastructure was fundamental. New roads, an airport, schools and hospitals had to be built and sanitary conditions improved. Data for this variable are not available and road density, *ROADD*, will be used as a proxy. Roads represent one important source of government expenditures and are associated with economic and demographic growth. The variable *ROADD* is calculated by dividing the extension of federal and state paved and unpaved roads by the area of each municipality. *ROADD* is expected to be directly related to the change in deforestation.

The variable ΔGDP is intended to show economic activity effects on deforestation. Higher income levels proportionate higher purchase power, which implies in increasing demand for goods and services over time. This study suggests that on mid-earlier stages of the free zone higher economic activity did not greatly affect deforestation because most goods and services consumed by local markets were imported from elsewhere. As time went by, economic activity might have played a more important role on deforestation because of the increasing demand for local goods like lumber for

houses and civil construction. The sign between ΔGDP and changes in deforestation is expected to be positive.

Economic incentives are an important factor for the Amazonas' economy. Detailed data for this variable, however, are very difficult to be obtained. Because of this difficulty, a variable for economic incentives is not used here. However, it is noteworthy that CAP and ΔGDP capture the effect of these incentives.

The Econometric Method

The models proposed by equations 13 and 20 are tested using OLS regressions for 1985. The regression is structured as follows:

$$\Delta D8580_i = \alpha_0 + \alpha_1 ROADD_i + \alpha_2 SEC_i + \alpha_3 CAP_i + \alpha_4 \Delta D8075_i + \alpha_5 \Delta GDP_i + \varepsilon_i \qquad (21)$$

where

$$\varepsilon_i \sim i.i.d.\ (0,\ \sigma^2).$$

Equation 21 represents the basic relationship suggested by the theoretical models. The empirical model is assumed to have the usual properties of the classical linear regression models (see Green, 1990). Particularly, the error term is assumed to be normally distributed with zero mean and constant variance, σ^2.

CHAPTER 7

RESULTS AND DISCUSSION

This chapter will present the results of the empirical model and discuss them. The presentation will be divided in two parts. The first part will show some econometric tests as well as coefficient estimates. The second part discusses the empirical results and their relationship with the theoretical explanations.

Results

The results of the OLS estimations for deforestation specified by Equation 21 are shown in Table 13. The table shows the results for 1985 and the respective elasticities. Several alternative arrangements were performed to find the best fit, and Equation 21 is representative of this effort. The table also shows a summary of statistics to be used in hypothesis testing of the model significance[33]. The equation's R-square and the *F* statistics are provided in Table 13. The White Test was performed for all variables used in the empirical estimations.

[33] The models were estimated using LIMPED 7.0 on a personal computer.

Table 13 – OLS results for change in deforestation (*ΔD8580*) for 1985 and respective elasticities

Independent Variables	1985	elasticities (%)[a]
Constant	- 2.92	
	(-0.06)	
DEF80	-0.93	-3.07
	(-3.83)	
ROADD	15305	2.33
	(3.71)	
CAP	-0.92×10^{-4}	-16.2
	(-4.37)	
SEC	0.64	11.8
	(3.80)	
ΔGDP	0.50×10^{-6}	6.24
	(1.95)	
R-square	0.53	
F-Test	6.48	
N = 34		

Note: numbers are estimated coefficients, and numbers in parentheses are *t*-statistic. All numbers were rounded for two decimals.

[a] Calculated using the formula: $\varepsilon_{yx} = \frac{\Delta Y}{\Delta X} \cdot \frac{\bar{X}}{\bar{Y}}$.

The R-square for the Model is 0.53. This result indicates that the model is able to explain fifty-three percent of the its variation. This is a reasonable result considering that this is a cross-sectional study. The *F* statistic is a joint test to test the null hypothesis (H_0) that all the slope coefficients are zero (Greene, 1993). The critical value for this model at five-percent significance level is close to 2.56. This critical value, therefore, fails to accept H_0 for the model. The White Test examines whether the error variance is affected by any of the regressors, their squares or their cross-products (Kennedy, 1994). All

variables were tested going up to the fourth power[34]. The null hypothesis of homoskedasticity failed to be rejected for all variables.

Past deforestation (*DEF80*) had a negative influence on the change of deforestation between 1985 and 1980. According to the estimations, higher deforestation levels in 1980 led to negative changes in deforestation in 1985. This is a possible outcome because in Amazonas agricultural activities are not strongly characterized by the kind of shifting cultivation that happens in Rondônia and south Pará. The elasticity of deforestation in 1980 with respect to the dependent variable shows that a one-percent increase in *DEF80* leads to 3.07% decrease in the change of deforestation.

Road density significantly and directly affected the change in deforestation and had the expected sign. The elasticity for this variable, however, was the lowest one. This suggests that roads as an approximation for government investments played important role in how deforestation changed, but that their impacts were not as strong as expected.

Physical capital (*CAP*), which was approximated by the consumption of industrial electricity, had the expected sign. Capital was the input receiving economic incentives. This study argues that due to the weak connection that industries had with local inputs, capital had adverse effect on the change of deforestation. This argument also showed to be statistically significant. In addition, its elasticity at –16.2, with respect to the change in deforestation was the one presenting higher absolute value in the model.

Secondary education yielded a significant coefficient and related positively with changes in deforestation. In ideal terms, this variable should have a positive sign. The

[34] The test was performed as suggested by Pindyck and Rubinfeld (1991, p.p. 136-7).

reason for this is because common sense would suggest that more educated people should care more about environmental problems and, therefore, to contribute to lower deforestation caused by some forms of anthropogenic actions. Three points are argued in an attempt to understand the sign resulted from the regression. The first one is that *SEC* is an approximation to evaluate the role of human capital in the model. As an approximation it is subjected to many imperfections and because of that it may have failed to achieve the expectation. A second aspect that might have affected the sign of *SEC* is the fact that it captured population rather than skill of people. This is not hard to understand. In Amazonas, most secondary schools are located in a few main cities. There are many municipalities that simply do not have this level of school. Thus, searching for better opportunities people move to those main cities where they can study and work. Finally and still complementing the latter alternative, the age and labor force structure was not incorporated in the model. Thus, the result can also be reflecting a directed growth in population. The elasticity for this variable is 11.8%.

Changes in *GDP* are not present in the theoretical model developed in Chapter 4. However, it is a contention of this study that the lagged effect of income did affect current changes in deforestation. From a simplistic perspective, economic activity can be allocated to satisfy both current and future consumption. If initial level of consumption is low, economic activity will be used to satisfy short-term needs. This behavior can change in the long run. As explained earlier, as the policy moved away from its initial point greater economic activity proportionate a diversification in demand for local resources (e.g.: lumber and land for housing). Thus, the variable ΔGDP captures these aspects and

it is marginally significant at the five-percent level. Its elasticity is 6.24%, which indicates its moderate effect on changes of deforestation as compared to other variables having positive effect on the latter.

Discussion of the Results

The regressions were based on the solutions of the optimized models presented by Equations 13 and 20. As discussed above, there were some limitations relative to the quantity and quality of the data used to test the hypotheses presented in Chapter 4. One difficulty for example was to find the proper data to test how economic incentives affected economic growth. This problem also suffered from the fact there was no cross-sectional variation in the degree of economic incentives, in addition to the correlation of incentives and other economic variables over time. Several attempts were made to use the complete available data set. Initially, a four-time period panel analysis with fixed and random effects was performed but preliminary results indicated some problems probably related to the assumption of normality of the error terms. Later, separate OLS regressions for 1980 and 1985 were carried out but not used because of data problems of some relevant variables for 1980 and 1975 were poor.

An interesting observation that the estimations show relates to past deforestation. The variable *DEF80* showed that deforestation between 1985/80 had negative influence on changes of deforestation in 1985. This suggests that activities leading to deforestation in Amazonas were different from those that took place in other areas of Amazonia. For

example, one characteristic of the slash-and–burn agriculture is that land is cleared and used for a certain period, and then abandoned or used for other purpose. In this case there is always addition of new land to the activity, which implies in more cleared land and deforestation. Thus, unless there were no forest left for deforestation, which is not the case of Amazonas, *DEF80* would be expected to have a positive sign.

Road density, which was used to proxy government investment, was highly significant. This is not a surprising result. The tropical deforestation literature has indicated that roads are a leading factor contributing to deforestation. Roads also mean a means to economic development. The significance of the variable also matches with the argument presented by Reis and Margulis (1991, p.16). That is, from 1975 on the process of expansion of roads became more decentralized and states and municipalities started to play more important role on the development of the Amazonia's road network. It is important to reinforce that even though the variable presented significant coefficient, its elasticity was the lowest one.

Human capital affected changes in deforestation directly while physical capital affected it inversely. The objective of *SEC* was to incorporate in the analysis how human capital affected deforestation. Note that results go against expectations, but are reasonable given broader definition that included influence of urban population. On the other hand, physical capital was introduced because it is the production factor receiving economic incentives, therefore, the heart of the policy. The presence of this variable is essential for this model.

Many variations were tried using both types of capital together and separately but most of the combinations did not perform well. It was expected, though, that the combination used by Wood and Kesti (1997) and Owens and Wood (1997), that is, skill per worker would yield significant results. This approach may not be a good one when such level of urban concentration is present. For example, the demographic density for the State of Amazonas is very low but there is high population concentration in Manaus and surrounding cities. This low demographic density associated with high urban concentration probably dissipated all significant information that was useful in those authors' work. The approach used by De Paula (1996) was not possible either. One problem that affected both alternatives was that there were no ways to stratify the population data by desirable characteristics. For example, there was no way to find the percentage of workers in the urban population.

The second hypothesis presented in Chapter 4 states that there is a negative association between the Amazonas State economic growth and the increase in its deforested area. The estimated model showed that the performance of the State's economy, as measured by ΔGDP had borderline statically significant direct effect on changes in deforestation. Earlier in this study it was argued that the reason economic activity and *CAP*—understanding the latter as an approximation of economic activity—affected adversely deforestation was because the higher income levels lead to increasing import of many goods, particularly agricultural goods, and lessened the pressure on forest conversion to agricultural lands. Therefore, there was a substitution effect between local and imported goods. However, it was also explained that there was an inverse trend

caused by the increasing demand for other resources like forest goods and lumber for housing and civil construction. Thus, by 1985 this latter effect seems to have outweighed the former.

CHAPTER 8

CONCLUSIONS

This chapter finalizes the research, presenting the main conclusions and indicating some of its policy implications in an attempt to proportionate a practical result. The limitations of the study are discussed next and finally, a research agenda is presented.

This research analyzed the role of the Manaus Free Zone (MFZ), a Brazilian program to promote development in the State of Amazonas. The policy issue considered is related to the social efficiency of economic incentives and its impact on deforestation, which is one form of social benefit (or cost). The years under review were 1980 and 1985. The analysis used cross-sectional data and was performed through Ordinary Least Square (OLS) regressions for 1985.

The results of this study indicate that economic incentives to promote economic growth in Amazonas affected changes in deforestation in two ways: (1) directly through changes in GDP and (2) inversely through the increase in the stock of industrial physical capital. Economic incentives are generally criticized because they can potentially introduce inefficiency in economic systems. On the other hand, some advocates of subsidies support the use of this mechanism based on equity grounds. The Manaus Free Zone served as a bridge to guarantee the Brazilian presence in Amazonia at the same time that had little effect on the deforestation of the State. On one hand MFZ helped to reduce

the demographic emptiness in Amazonas, on the other it demonstrates to have a weak connection with local resources. Its effect on deforestation seems to have happened more as a consequence of demographic and income growth rather than by the industrial demand pressure for local inputs. On efficiency grounds and from the national perspective, this weakness is a relevant point because if the situation persists over time, the justification of the social cost of economic incentives to the rest of the country will be more and more difficult. On the other hand, the strategic presence of Brazilians in the region contributes to maintaining the national territory and its richness.

It is also relevant to note that even though the sign of the variable *DGDP* was positive, it does not mean that lower increments in income will lead to lower future deforestation. In real life it can move in both directions. If the economic activity decelerate to levels that compromise the basic consumption needs, deforestation can increase because cheaper marginal resources (usually natural resources) are going to be used first at rates far above the social optimum. On the other hand, if parallel measures are not taken timely the growing scale of the local economy will also exacerbate deforestation.

From the rest of the world's perspective, it seems that the MFZ policy produced a positive externality as compared to other activities contributing to deforestation. It is noteworthy that the general level of deforestation of the State is very low relative to other states in the region.

Keeping in mind that the study analyzes two periods that are thirteen and eighteen years away from the formal start of the policy, one main conclusion can be drawn. The

policy is a feasible alternative to promote sustainable economic growth but for its own survival it is crucial to change its course towards alternatives balancing efficiency and equity. From the efficiency point of view, the policy should seek more independence from economic incentives and look at sustainable paths for the use of regional resources (human and natural). From the equity perspective, the rest of the country and the world should be more informed that even though the policy has some economic burden (but relatively low), it plays an important role to the conservation of that natural patrimony.

Policy Implications

As a result of the analysis developed in this research, some suggestions can be made in order to contribute to the development of economic and environmental policies in Amazonas. The suggestions will be divided in two categories: Economic-Social and Environmental.

Deforestation is a serious threat to the health of the planet and consequently to people. In the case of Amazonas, which has a large share of the world's tropical forests, government policies should put emphasis on policies that can affect the source of the causes of the problem. More educated workers is an indication that people go to school and learn more about the relationships between the socio-economic and natural systems. If that is the case, people can better contribute to conservation of the natural environment and benefit from it. More education on all levels and categories (ordinary and technical) are extremely important.

Capital and new investments are already well known as the main propellants of any economy. The natural environment has also to be seen in the same way. There are important connections among natural and economic systems that cannot be overlooked. Economic development in Amazonas can not depend solely on the presence of economic incentives. Research and development seeking more participation of regional inputs in the economy is fundamental. This task has to be carried out *pari passu* with ecological and social studies aiming at the optimization of the use of natural, human-made and human capital. The way that these elements have to be synchronized and combined depends on a plan that governments must develop and implement. Any imbalance or delay on this process can lead to unsustainable economic development.

Special attention should be given to roads. Roads are pointed as one important factor leading to deforestation, and governments are the primary road builders. Roads, however, represent an important element for development. Government should constrain the construction of roads based on zoning plans. Indiscriminate road construction or any unplanned means of surface transportation can lead to a false perspective of development.

Limitations of the Present Study

The mathematical model has some limitations related to the specification of the production function of the economy. The first formulation considered a Cobb-Douglas relationship while the second was a quadratic one. Both specifications suffer from some technical constraints that can be addressed using more complex formulations. Another

limitation in the mathematical model was the linear specification of the state equation for investment. Other formats such as the exponential relationship between interest rates and investment should be used to better incorporate the role of investment in the model.

The main limitation of this study was the availability and the quality of the data for econometric testing. Some economic variables were not tested directly because of the lack of data. Proxies were used for these variables and could limit findings. As mentioned earlier, data for economic incentives were very poor. The quality of the data is also another point to be considered. An important portion of the data set used in this study is a result of a tremendous effort of the *Instituto de Pesquisa Econômica e Aplicada* in Rio de Janeiro that gathers them from different sources. Lack of knowledge of methodological issues and collection errors from these sources are important considerations. The author also observed the same aspects in the data that he collected. This data set represents the best information available, though.

Suggestions for Future Research

Based on the findings of this study it is possible to develop a research agenda following two main lines. One is the improvement of the present research and the other is the diversification of the subject. At the local level, more research can be developed to understand how incentives contributed to affect the quality of the urban environment in more populated areas of Amazonas. More research can also be developed to understand equity and efficiency issues associated with economic incentives. For example, what is

the impact of one additional million dollars of incentives on the creation and maintenance of jobs in the State and other areas of the country? Does the policy represent a net cost or net benefit to the country?

From the national perspective, a research agenda considering how the per capita gains affect migration to the area may indicate whether or not this kind of policy can be safely replicated in Amazonia as an alternative to promote economic development. For example, if more resources were used to stimulate the growth of the free zone (or free zones) would it mean a transfer of pressure on deforestation from southern to western Amazonia, or would it simply mean the stimulation of one more source of deforestation?

Finally, research on the public finance side of the policy can be undertaken. This research can focus on the simulation of the impacts of changes on macroeconomic policies (like termination or substantial reduction of the level of economic incentives) with potential adverse effects to the economy of the State. In addition, future research can also address how the State would act to face such adversities and still be able to create alternatives to maintain an acceptable and desirable level of economic development.

LIST OF REFERENCES

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A Crítica, 04/25/1997. http://www/acritica.com.br.

Almeida, A. L. O. de, 1992. *Colonização Dirigida na Amazônia*. Rio de Janeiro: IPEA.

Almeida, A. L. Ozório de and J. S. Campari, 1995. *Sustainable Settlement in the Brazilian Amazon*. New York: Oxford University Press.

Andersen, E. L., C.W. J. Granger, L. Huang, Eustáquio, J. R., and D. Weinhold, 1996. Report on Amazon Deforestation. Photocopy.

Aragón, L.E., 1993. Amazônia Questões Globais e Regionais. In *Bases Científicas para Estratégias de Preservação e Desenvolvimento da Amazônia*, eds. E.J.G Ferreira, G.M Santos, E.L.M Leão, and L.A Oliveira. Vol 2, 243-248. Manaus: INPA.

Baer, W., 1995. *The Brazilian Economy: Growth and Development*. 4th Ed. Westport, CT: Praeger Publishers.

Bahiana, L.C., 1991. O Norte na Organização Regional do Brasil. In *Geografia do Brasil - Região Norte*. Rio de Janeiro, RJ: FIBGE.

Barcellos, M. M. and W. I. S Costa, 1991. População. In *Geografia do Brasil - Região Norte*. Rio de Janeiro, RJ: FIBGE.

Becker, B. K., 1995. Undoing Myths: The Amazonia - An Urbanized Forest. *Brazilian Perspectives on Sustainable Development of the Amazonia Region*, ed. Clusener-Got and I. Sachs (Man & the Biosphere Series; Vol. 15). Paris, France: Ed. UNESCO.

Benchimol, S., 1995. *Amazônia Fiscal 1994: Bonanças e Desafios*. Universidade do Amazonas, Manaus, AM.

_____, 1966. *Estrutura Geo-Social e Econômica da Amazônia*. Vol II. Governo do Estado do Amazonas, Manaus, AM.

_____, 1989. *Free Zone of Manaus: the Coming of Age*. São Paulo: Sver & Boccato.

Billsborrow, R. and M. Geores, 1994. Population, Land-Use, and the Environment

in Developing Countries: What Can We Learn from Cross-National Data? In *The Causes of Tropical Deforestation, The Economic and Statistical Analysis of Factors Giving Rise to the Loss of Tropical Forests*, eds. D.W. Pearce and K. Brown. London: University College London Press Limited.

Bluffstone, R. A., 1995. The Effect of Labor Market Performance on Deforestation in Developing Countries Under Open Access: An Example from Rural Nepal. *Journal of Environmental Economics and Management* 29:42-63.

Bohrer, C.B de A., and Gonçalves L.M.C., 1991. Vegetação. In *Geografia do Brasil - Região Norte*. Rio de Janeiro, RJ: FIBGE.

Castello Branco, M. L. G., 1991. Indústria. In *Geografia do Brasil - Região Norte*. Rio de Janeiro, RJ: FIBGE.

CIMA – Comissão Interministerial para a Preparação da Conferência das Nações Unidas sobre o Meio Ambiente e Desenvolvimento, 1991. *Subsídios Técnicos para a Elaboração do Relatório Nacional do Brasil para a CNUMAD*. Versão Preliminar. Brasília, DF.

DNPN - Departamento Nacional de Produção Mineral, 1978. *Projeto RADAMBRASIL*. Rio de Janeiro.

Dore, H.I. M. and J.M. Nogueira, 1993. Sustainable Development and the Amazon Rainforest. Proceedings of the 25th International Symposium, Remote Sensing and Global Environmental Changes. Vol. 2.Graz, Australia.

Fearnside, P. M., 1993. Migração, Colonização e Meio-Ambiente: O Potencial dos Ecossistemas Amazônicos. In *Bases Científicas para Estratégias de Preservação e Desenvolvimento da Amazônia*, eds. E.J.G Ferreira, G.M Santos, E.L.M Leão, and L.A Oliveira. Vol 2, *243-248*. Manaus: INPA.

FGV - Fundação Getúlio Vargas, 1996. Análise da Evolução do Produto Interno Bruto por Estados de 1970 a 1995. *Estados e Municípios*. Ano 8. Rio de Janeiro.

FIBGE - Fundação Instituto Brasileiro de Geografia e Estatística, 1998. http://www.ibge.gov.br.

_____, 1990b.
Estatísticas Hisóricas do Brasil: Séries Econômicas, Demográficas e Sociais de 1550 a 1988. 2.ed. Vol.3. Rio de Janeiro.

_____, 1990c. *Projeto Zoneamento das Potencialidades dos Recursos Naturais da Amazônia Legal*. Rio de Janeiro.

Frischtak, C. R., E. A. Guimarães, P. B. Tigre, and C.N. Zonenscain, 1994. *Programa de Competitividade Sistêmica da Zona Franca de Manaus*. Rio de Janeiro: Instituto Nacional de Altos Estudos - INAE.

Governo do Amazonas. Various years. Anauário Estatístico do Amazonas. Manaus.

Greene, W. H., 1993. *Econometric Analysis*. New York: Macmillan Publishing Company.

Greene, W.H., *1998. LIMDEP User's Manual Version 7.0.* http://econwpa.wustl.edu/limdep/lim.htm

Grossman, G.M. and A.B Krueger, 1995. Economic Growth and the Environment. The Quarterly Journal of Economics 110(2): 353-377.

IDB/UNDP/ACT, 1992. *Amazonia Without Myths*.

INPE - Instituto Nacional de Pesquisas Espaciais, 1998. http://www.inpe.br/amazonia/

IPEA - Instituto de Pesquisa Econômica e Aplicada, 1996. DESMAT – Dados Ecológicos e Sociais para os Municípios da Amazonia Tropical. Data Base. Rio de Janeiro.

Kahn, J.R. and J.A. McDonald, 1995. Third World Debt and Tropical Deforestation. *Ecological Economics* (12) 107-123.

Kamien, M.I. and N.L Schwartz, 1981. *Dynamic Optimization: the Calculus of Variation and Optimal Control in Economics and Management*. New York, NY: North-Holland.

Kennedy, P., 1994. *A Guide to Econometrics*. Cambridge: The MIT Press.

Kummer, D. M. and C. H. Sham, 1994. The Causes of Tropical Deforestation: A Quantitative Analysis and Case Study from the Philippines. In *The Causes of Tropical Deforestation, The Economic and Statistical Analysis of Factors Giving Rise to the Loss of Tropical Forests,* Eds. D. W. Pearce and K. Brown. London: University College London Press.

Kumi, H. and G.Piani, 1997. *A indústria da Zona Franca de Manaus: uma Avaliação da Proteção Recente.* Versão 1. Convênio BNDES/IPEA.

Lombardini, C., 1994. Deforestation in Thailand. In *The Causes of Tropical Deforestation, The Economic and Statistical Analysis of Factors Giving Rise to the Loss of Tropical Forests* , eds. D.W. Pearce and K. Brown. London: University College London Press Limited.

Lyra, F. Tavares, 1995. Os Incentivos Fiscais à Zona Franca de Manaus: Uma Avaliação (Relatório Final). *Texto Para Discussão nº. 371.* Brasília: IPEA.

Martelli, A., 1969. *Amazônia: Nova Dimensão do Brasil.* Petrópolis, RJ: Editora Vozes Ltda.

Mello, M. Lacerda de and H. A. de Moura, 1990. *Migrações para Manaus.*Recife, PE: FUNDAJ, Editora Massangana.

Nimer, E., 1991. Clima. In *Geografia do Brasil - Região Norte.* Rio de Janeiro, RJ: FIBGE.

Osgood, D., 1994. Government Failure and Deforestation in Indonesia. In *The Causes of Tropical Deforestation, The Economic and Statistical Analysis of Factors Giving Rise to the Loss of Tropical Forests* , eds. D.W. Pearce and K. Brown. London: University College London Press Limited.

Owens, T and A. Wood, 1997.Export-Oriented Industrialization Through Primary Processing? *World Development*, Vol. 25, No 9, pp. 1453-1470.

Paiva, M.E. de, C.de S. Carreira and S. de Mattos. Agropecuária. In *Geografia do Brasil -Região Norte.* Rio de Janeiro, RJ: FIBGE.

Palo, M., 1994. Population and Deforestation. In *The Causes of Tropical Deforestation: The economic and Statistical Analysis of Factors Giving Rise to the Loss of the Tropical Forests,* eds. K. Brown and D.W. Pearce. London: University College London Press Limited

Paula, Luiz A. de., 1996. Cross Sectional Study of Growth in Developed and Developing Countries: an Analysis of the Endogeneity of Human Capital and Income Inequality. The University of Tennessee. Ph.D. Dissertation.

Pearce, D and K. Brown, 1994. Saving the World's Tropical Forest. In *The Causes of Tropical Deforestation: The economic and Statistical Analysis of Factors Giving Rise to the Loss of the Tropical Forests*, Eds. D.W. Pearce and K. Brown. London: University College London Press Limited.

Persson, A. and M. Munasinghe, 1995. Natural Resource Management and Economywide Policies in Costa Rica: a Computable General Equilibrium Modeling Approach. *World Bank Economic Review*, vol. 9(2), pp. 259-285.

Pindyck, R. S. and D.L. Rubinfeld, 1991. Econometric Models and Economic Forecast. 3rd Ed. McGraw-Hill, New York.

Reis, J. E. and S. Margulis, 1991. Perspectivas Econômicas do Desflorestamento da Amaônia. *Texto para Discussão*. No. 215 Rio de Janeiro: IPEA.

Reis, J. E. and R. Guzmán, 1994. An Econometric Model of Amazon Deforestation. *The Causes of Tropical Deforestation, The Economic and Statistical Analysis of Factors Giving Rise to the Loss of Tropical Forests,* eds. D. W. Pearce and K. Brown. London: University College London Press Limited.

_____, 1993. Um Modelo Econométrico do Deflorestamento da Amazônia. *Pesquisa e Planejamento Econômico* 23(1):33-64.

Reis, J. E. and S. Margulis, 1991. Options for Slowing Amazon Jungle Clearing. In *Global Warming: Economic Policy Responses,* eds Rudiger Dornbusch and James M. Poterba. Cambridge, MA: MIT Press.

Skole, D. L., W.H. Chomentowski, W. A Salas, and A. D. Nobre, 1994. Physical and human dimensions of deforestation in Amazonia. *BioScience*. 44(5): 314-322.

Soares, L. de C., 1991. Hidrografia. In *Geografia do Brasil - Região Norte*. Rio de Janeiro, RJ: FIBGE.

Southgate, D., R. Sierra, and L. Brown, 1991. The Causes of Tropical Deforestation in Ecuador: A Statistical Analysis. *World Development* 19(9): 1145-1151. (Also published by IIED, LLEC Paper 89-09, 1989.)

Souza, C. G., 1991. Solos. In *Geografia do Brasil - Região Norte*. Rio de Janeiro, RJ: FIBGE.

SUFRAMA - Superintendencia da Zona Franca de Manaus, 1998. http://manaus.pegasus.com.br/suframa/default.htm.

_____, 1993. *Zona Franca de Manaus : Histórico, Incentivos, Políticas e Perspectivas Atuais*, Brouchure.

Veja, 1997. *Amazônia: um Tesouro Ameaçado*. Edição Especial. Editora Abril.

Wiebelt, M., 1995. Stopping Deforestation in the Amazon: Trade-off between Ecological and Economic Targets? *Weltwirtschaftliches Archiv - Review of World Economics* 131 (Heft 3): 542-568.

_____, 1994. *Protecting Brazil's Tropical Forest, A CGE Analysis of Macroeconomic, Sectoral, and Regional Policies*. Kiel Working Paper #638, The Kiel Institute of World Economics.

Wood, A. and B. Kersti, 1997. Exporting Manufactures: Human Resources, Natural Resources, and Trade Policy.*The Journal of Development Studies*. Vol. 34, No. 1, pp.35-59.

World Bank, 1992. *Word Development Report 1992: Development and the Environment*. New York: Oxford University Press.

Zerbe, R.O. and D.D. Dively, 1994. *Benefit-Cost Analysis in Theory and Practice*. New York, NY: HarperCollins College Publishers.

APPENDIX

Appendix 1 - Territorial Division of the Amazonas State with Geographic Indication of Meso-regions, Micro-regions and Municipalities – 1991.

Meso-region	Micro-region	Municipality
North	Rio Negro	Barcelos*
		Novo Airão*
		Santa Isabel do Rio Negro*
		São Gabriel da Cachoeira*
	Japurá	Japurá*
		Maraã*
Southwest	Alto Solimões	Amatura
		Atalaia do Norte*
		Benjamin Constant*
		Fonte Boa*
		Jutaí*
		Santo Antônio do Içá*
		São Paulo de Olivença*
		Tabatinga
		Tonantins
	Juruá	Carauari*
		Eirunepé*
		Envira*
		Guajará
		Ipixuna*
		Itamarati
		Juruá*
Central	Tefé	Alvarães
		Tefé*
		Uarini
	Coari	Anamã
		Anori*
		Beruri
		Caapiranga
		Coari*
		Codajás*
	Manaus	Autazes*
		Careiro*
		Careiro da Várzea
		Manacapuru*
		Manaquiri
		Manaus*
	Rio Preto da Eva	Presidente Figueiredo
		Rio Preto da Eva

* Municipalities used in the estimations

Appendix 1 (continued)

Meso-region	Micro-region	Municipality
	Itacoatiara	Itacoatiara*
		Itapiranga*
		Nova Olinda do Norte*
		Silves*
		Urucurituba*
	Parintins	Barreirinha*
		Boa Vista do Ramos
		Maués*
		Nhamundá*
		Parintins*
		São Sebastião do Uatumã
		Urucará*
South	Boca do Acre	Boca do Acre*
		Pauini*
	Purus	Canutama*
		Lábrea*
		Tapauá*
	Madeira	Apuí
		Borba*
		Humaita*
		Manicoré*
		Novo Aripuanã*

* Municipalities used in the estimations

Appendix 2 - Brazilian North Region's GDP, by state, in 1980 million of US dollars

State	1970	1975	1980	1985	1990	1995
Acre	42	84	272	454	563	673
Amapá	37	64	165	259	338	432
Amazonas	227	795	2543	3956	5255	6245
Pará	363	1116	3859	4216	5442	6341
Rondônia	34	128	533	811	1164	1393
Roraima	6	36	99	195	338	673
North Region	709	2233	7471	9982	13100	17005
Brazil	33027	105962	233333	327619	376089	480361

Source: FGV (1996).

Appendix 3 – North Region's per capita GDP in absolute thousand of US dollars

State	1970	1975	1980	1985	1990	1995
Acre	195	330	903	1300	1350	1432
Amapá	324	452	941	1178	1171	1249
Amazonas	238	680	1778	2322	2499	2581
Pará	168	411	1134	1023	1050	1050
Rondônia	306	548	1085	1130	1029	910
Roraima	147	633	1251	1561	1565	2162
North Region	197	485	1271	1318	1277	1354
Brazil	355	1006	1961	2502	2560	3028

Source: FGV (1996).

Appendix 4 - Estimates of the lost revenue from import (II), industrialized goods (IPI) and sales (ICMS) tax for the Manaus Free Zone between 1990 and 1997 in US$ 1,000 [1]

	1990[2]	**1991**[2]	**1992**[2]	**1993**[2]	**1994**[2]	**1995**[2]	**1996**[3]	**1997**[3]
Brazil	1383956	904176	659856	1458576	1846110	2262776	2259978	2586728
II	467977	309080	235994	399806	320959	395990	584794	667034
IPI	915979	595096	423862	1058770	1525151	1866785	1675184	1919694
ICMS (AM)	476025	326094	277593	392951	428194	463771[4]	-	-
ICMS (Other states)	208795	156350	98308	134850	256558	193417[4]	-	-
Total	2068776	1386620	1035757	1986377	2530862	2919964	2259978	2586728

Source: SUFRAMA: Estatísticas de Importações e Levantamentos Conjunturais; Governo do Estado do AM/SEFAZ; MINIFAZ/ 2 ª RF
(1) SUFRAMA/CEE
(2) Situation *ex-post*
(3) Situation *ex-ante*, estimates made to the SRF for demostration of fiscal benefits as part of the Brazilian budget proposal.
(4) For Manaus only.
Conversions: US$ x CR$: 1990) CR$ 0,07 ; 1991) CR$ 0,40 ; 1992) CR$ 4,51 ; 1993) CR$ 88,45 ; 1994) Jan/Jun =CR$ 1.116,84. US$ x R$: Jul/Dec=R$ 0,87 ; 1995) R$ 0,918 ; 1996) R$ 1,00.
Conventions: "-" data not available for estiamtes.
Complementary information: Coordenadoria de Estudos Empresariais : 95%+ Manaus; IPI 70 + constant; Before 90 taxes were very concentrated in the MFZ/BR, especially II.

VITA

Alexandre Almir Ferreira Rivas was born in Manaus, Amazonas, Brazil on December 2, 1963. He attended primary and secondary school in Manaus, the capital of Amazonas. He entered the University of Amazonas in 1984 and transferred to the Federal University Ceará in the following year where he received the degree of Bachelor in Fishery Engineering in January 1988. He worked for one year and half in the Federal Agency for Development of the Sao Francisco River Valley in Minas Gerais. During this time he also worked as independent consultant for the government of Minas Gerais. In 1990 he entered the Federal University of Amazonas as an auxiliary professor. In May of 1997, he received a Master of Arts in Economics from the University of Tennessee. In May 1998, he received the Doctor of Philosophy degree in Economics from the University of Tennessee.