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Incentivizing Biodiversity Conservation: The Ecological ICMS in Brazil

Erin Franks

Claremont McKenna College

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CLAREMONT McKENNA COLLEGE

**INCENTIVIZING BIODIVERSITY CONSERVATION:
THE ECOLOGICAL ICMS IN BRAZIL**

SUBMITTED TO

PROFESSOR SERKAN OZBEKLIK

AND

DEAN GREGORY HESS

BY

ERIN FRANKS

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CHAPTER I. INTRODUCTION

The Amazon rainforest is the largest moist tropical forest in the world, covering over 5.4 million km² in 2001, an area almost half the size of the United States.¹ Since its beginnings during the Cretaceous period, the Amazon has provided a host of ecological services both regionally and globally. The Amazon is a bastion of biodiversity; roughly a quarter of the total known terrestrial animal species in the world live within its boundaries, and many more remain undiscovered.² Nutrient cycling by Amazonian plants enhances agricultural productivity,³ and recent research indicates that the ecosystems of the Amazon Basin play a major role in regulating local and global climate patterns. Particularly important is transpiration, the process whereby trees convey water from up to 10 m beneath the ground to their leaves, where it is released into the atmosphere. In this way, approximately 25-50% of the water of the Amazon Basin is recycled.⁴ When areas are deforested, local weather shows a marked decrease in precipitation, especially during the dry season.⁵ Without the Amazon's presence to maintain moisture in the atmosphere, rain patterns throughout nearby areas of South America would lose a major buffer against drought in drier years. At the global scale, the Amazon serves as a net

¹ Yadvinder Malhi et al., "Climate Change, Deforestation, and the Fate of the Amazon," *Science* 319, no. 169 (January, 2008), 169.

² Ibid., 169

³ Philip M. Fearnside, "Deforestation in the Brazilian Amazonia: History, Rates, and Consequences," *Conservation Biology* 19, no. 3 (June, 2005), 683. Jonathan A. Foley et al., "Amazonia Revealed: Forest Degradation and Loss of Ecosystem Goods and Services in the Amazon Basin," *Frontiers in Ecology and the Environment* 5, no. 1 (February, 2007), 25.

⁴ Malhi et al., *Climate Change, Deforestation, and the Fate of the Amazon*, 169

⁵ Carlos A. Nobre, Piers J. Sellers, and Jagadish Shukla, "Amazonian Deforestation and Regional Climate Change," *Journal of Climate* 4 (October, 1991), 969.

carbon sink, making it a key resource in any long-term plan to combat human-driven climate change.⁶

Despite the myriad of ecosystem services provided by the Amazon, it was not recognized as an asset by the countries in which it lies for many decades. Beginning in the 1970s, the rate of deforestation in the Amazon increased greatly, especially in Brazil, where an average of 18,500 km² per year was deforested every year from 1988-2005, representing 80% of the total Amazonian deforestation during this time period.⁷ This destruction resulted in significant releases of carbon, with recent estimates suggesting that deforestation in Brazil during the 1980s and 1990s accounted for a net emission of approximately 0.2 petagrams (Pg) of carbon per year. When compared to the total amount of carbon released by deforestation in the tropics worldwide, which was around 0.75 Pg per year, the scale of impact on global climate becomes clearer: deforestation in the Amazon represented almost 5% of annual global carbon emissions during this period.⁸

As a result of the many ecosystem services it provides, the issue of deforestation in the Amazon is of enormous concern. Because Brazil has had the highest rate of deforestation of all Amazonian countries in the past few decades, international and domestic concern has led its government to seek strategies to reduce the problem.

⁶ Malhi et al., *Climate Change, Deforestation, and the Fate of the Amazon*, 169

⁷ "Project PRODES," Brazilian National Institute for Space Research, <http://www.obt.inpe.br/prodes/index.html> (accessed October 30, 2012, 2011).; Malhi et al., *Climate Change, Deforestation, and the Fate of the Amazon*, 169

⁸ Ruth S. DeFries et al., "Carbon Emissions from Tropical Deforestation and Regrowth Based on Satellite Observations for the 1980s and 1990s," *Proceedings of the National Academy of Sciences* 99, no. 22 (October, 2002), 14258-14259.

These efforts have been impressively effective in recent years, with only 6,200 km² of deforestation detected in 2011.⁹ Though this is a significant reduction from the levels of the 1990s, it still represents the annual loss of an area of forest the size of Delaware. In addition, these figures do not capture the impacts of forest degradation caused by selective logging and overhunting of threatened species.¹⁰ Though it is difficult to detect, degradation can have far-reaching impacts; for instance, selective logging can lead to up to 40% mortality of surrounding vegetation, and often results in the complete eradication of keystone species from an ecosystem.¹¹ Both the continued rate of deforestation and the unbridled degradation of the Amazon point to the need for innovative strategies for its protection.

One major approach to conservation has been to establish protected areas with limitations on the amount or type of resource extraction which can take place within their boundaries. In 2000, the Brazilian government implemented the National System of Conservation Units (*Sistema Nacional de Unidades de Conservação da Natureza*, SNUC) to consolidate and standardize regulation regarding previously-established protected areas.¹² The SNUC divides protected areas into two broad categories: integral protection (*proteção integral*), and sustainable use (*uso sustentável*). Integral protection areas include biological reserves, ecological stations, natural monuments, and wildlife refuges,

⁹ Project PRODES

¹⁰ Foley et al., *Amazonia Revealed: Forest Degradation and Loss of Ecosystem Goods and Services in the Amazon Basin*, 26-27

¹¹ Joyotee Smith et al., "Dynamics of the Agricultural Frontier in the Amazon and Savannas of Brazil: Analyzing the Impact of Policy and Technology," *Environmental Modeling and Assessment* 3 (1998), 33.

¹² M. A. Pedlowski et al., "Conservation Units: A New Deforestation Frontier in the Amazonian State of Rondônia, Brazil," *Environmental Conservation* 32, no. 2 (2005), 150.

and are characterized by little or no allowed human development within their territory. Sustainable use areas include extractive reserves and sustainable development reserves, and generally allow a limited amount of farming, logging, or other sustainable economic activities.¹³

Major efforts by the Brazilian government to increase the number of conservation units (*unidades de conservação*, CUs) have been very successful during the last few decades, with a significant increase in both integral protection and sustainable use CUs at the federal and state level.¹⁴ However, beginning in the early 1990s, municipal leaders began to complain about this increase, stating that the requirement to maintain federal lands within their borders carried a high opportunity cost, preventing those lands from being used for more lucrative alternative activities.¹⁵ This is a particularly important consideration in Brazil because of the way the tax structure is organized by the Federal Constitution of 1988. The main source of tax funds for states and municipalities is the Tax on Circulation of Goods and Services (*Imposto sobre a Circulação de Mercadorias e Prestação de Serviços de Transporte Interestadual e Intermunicipal e de Comunicação*, ICMS), a value-added tax collected by the state governments. According to the Constitution, 25% of the total funds collected at the state level must be redistributed to municipality governments and 75% of the funds that pass to municipalities must be

¹³ Normative Instruction no. 1 of May 5, 2010: State of Mato Grosso.

¹⁴ Russell A. Mittermeier et al., "A Brief History of Biodiversity Conservation in Brazil," *Conservation Biology* 19, no. 3 (June, 2005), 601-603.

¹⁵ Maryanne Grieg-Gran, *Fiscal Incentives for Biodiversity Conservation: The ICMS Ecológico in Brazil* (London, UK: International Institute for Environment and Development: Environmental Economics Programme, 2000), 1.

distributed according to where they were collected;¹⁶ therefore, the ability of municipalities to maintain functioning industries is vital to their incoming revenues.

However, with the right state policies, this rigid tax structure has proven to be not a barrier to the establishment of CUs, but a tool for their expansion. The opportunity lies in the fact that the remaining 25% of funds transferred from states to municipalities can be distributed according to any criteria chosen by the state. In 1991, the state of Paraná was the first to establish an ecological-based criterion for distribution of its ICMS funds.¹⁷ Five percent of the total funds given to municipalities was to be determined by the area of protected land within each municipality; the more protected area, the greater a municipality's share of the 5%. This innovative idea quickly spread, and as of 2012, fourteen of Brazil's 27 states have adopted some form of ecological ICMS (ICMS-e) criteria.¹⁸

While the ICMS-e has spread rapidly and is quite popular, few definitive efforts have been made to assess its effectiveness. Clearly, the inclusion of an ecological criterion will benefit municipalities which already maintain protected areas within their borders. However, one of the stated goals of the ICMS-e is to incentivize municipalities to create *new* protected areas. While the number and area of CUs has grown substantially during the same time period in which the ICMS-e has been implemented,

¹⁶ Further details regarding the structure and functioning of the ICMS are presented in Chapter II. Ibid., 1

¹⁷ Vinicius Duarte Ribeiro, "Ecological ICMS as an Instrument of Forest Policy" (Forestry Engineer, Federal Rural University of Rio De Janeiro, 2008), 6-7, <http://www.icmsecologico.org.br/images/artigos/a010.pdf> (accessed November 27, 2011).

¹⁸ "Ecological ICMS," The Nature Conservancy, <http://www.icmsecologico.org.br/> (accessed October 27, 2011).

this is unsurprising; CUs are, with very few exceptions, permanently designated, so it is impossible for their extent to decrease.¹⁹ In this case, simple correlation should not be taken as a sign that the ICMS-e is having its intended effect without further evidence directly linking its presence to the growth of protected areas.

Because of the popularity of the ICMS-e as a conservation tool, it is extremely important that its be assessed using a systematic, quantified method, something which has not been previously done. This study attempts to do just that by using econometric analysis of panel data of 807 municipalities within the states of the Legal Amazon (*Amazônia Legal*) to assess whether the presence of the ICMS-e had a significant effect on the increase in the number of protected areas during the period from 1999-2009.

¹⁹ Ibid.; Pedlowski et al., *Conservation Units: A New Deforestation Frontier in the Amazonian State of Rondônia, Brazil*, 150

CHAPTER II. HISTORICAL AND REGULATORY BACKGROUND

History of Deforestation in the Amazon

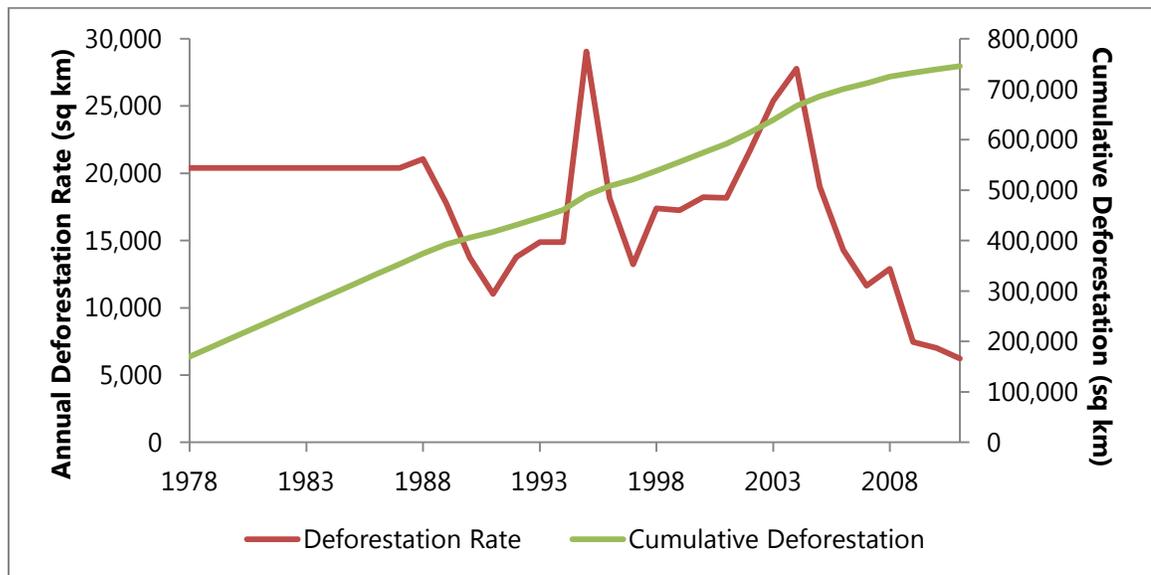
Up until the 20th century, the Amazon was ignored by the Brazilian government – it was viewed as a forbidding jungle, impassable except through major waterways, and inhabited by unfriendly indigenous groups, dangerous animals, and diseases. For the most part, human settlement during the colonial period occupied only areas along Brazil's Atlantic coastline. These areas experienced significant environmental impacts – the important Atlantic Forest ecosystem today only covers a mere 12% of its original extent.²⁰ However, the inland forests of the Amazon Basin escaped this devastation. Though there was some deforestation along the outer edges of the Amazon, the vast majority of the forest remained intact, with only 0.6% of the original extent deforested in 1975.²¹ This started to change during the 1970s, when Brazil's military government began to be concerned about securing its western borders. As a result, many programs were initiated to improve transportation and communication across the Amazon, to increase economic development within the Amazon, and to make greater use of the "wasted"

²⁰ Milton Cezar Ribeiro et al., "The Brazilian Atlantic Forest: How Much is Left, and how is the Remaining Forest Distributed? Implications for Conservation," *Biological Conservation* 142, no. 6 (2009), 1145.

²¹ Emilio F. Moran, "Deforestation and Land use in the Brazilian Amazon," *Human Ecology* 21, no. 1 (1993), 1.

forest resources.²² All these programs led to an exponential increase in the amount of deforestation; by 2003, 16.2% of the Amazon's original extent was gone (Figure 1).²³

Figure 1. Annual Deforestation Rate and Cumulative Deforestation in the Amazon, 1978-2011



Data Sources: 1977-1987: Fearnside, "Deforestation in the Brazilian Amazonia," 681. 1988-2011: INPE, Project PRODES.

Vital to the rise in deforestation in the Amazon was the building of roads which enabled access to deeper reaches of the forest. Almost all studies of the causes of deforestation worldwide point to the presence of roads as a significant contributing factor, and the Amazon is no exception.²⁴ Without roads, logging is prohibitively expensive due to transportation costs, farmers and ranchers cannot easily claim land, and

²² Onil Banerjee, Alexander J. Macpherson, and Janaki Alavalapati, "Toward a Policy of Sustainable Forest Management in Brazil: A Historical Analysis," *The Journal of Environmental Development* 18 (2009), 133-134.

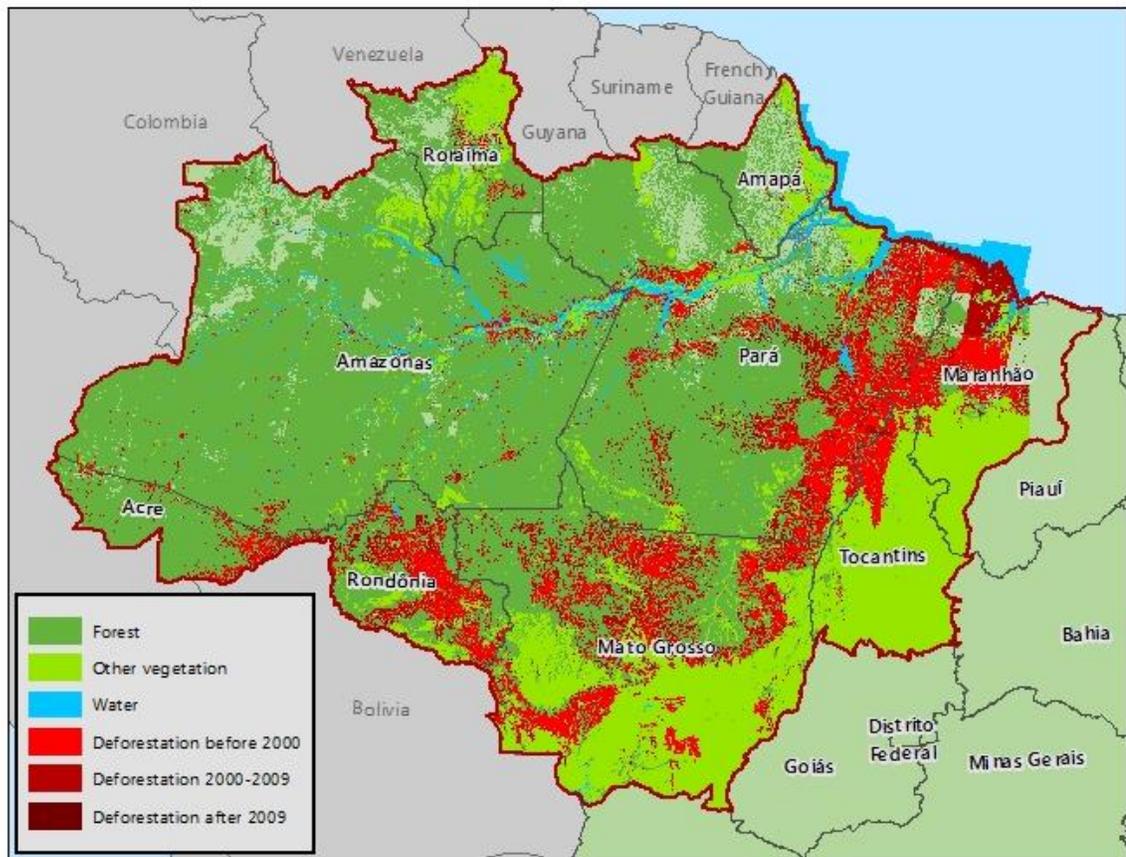
²³ Philip M. Fearnside, "Deforestation in the Brazilian Amazonia: History, Rates, and Consequences," *Conservation Biology* 19, no. 3 (June, 2005), 681.

²⁴ Andrea Cattaneo, "Deforestation in the Brazilian Amazon: Comparing the Impacts of Macroeconomic Shocks, Land Tenure, and Technological Change," *Land Economics* 77, no. 2 (May, 2001), 229-230.

settlers have little desire to establish themselves in locations far removed from cities and towns. The Transamazon highway, which runs east-west, and the Cuiabá-Santarem highway, which runs north-south, were built through the heart of the Amazon in the early 1970s as part of the military government's effort to connect the forest with the rest of Brazil. These highways, as well as the many feeder roads leading from them, gave ranchers, farmers, landless settlers, and loggers access to a greater area, and where road building occurred, massive deforestation followed.²⁵ The majority of historical deforestation is concentrated in the "Arc of Deforestation" along the southern and eastern edges of the Amazon, and along major roads and waterways (Figure 2). These patterns illustrate the importance of accessibility in determining where deforestation happens. No matter what other policies or incentives are in place, without access, it is almost impossible to clear land.

²⁵ Moran, *Deforestation and Land use in the Brazilian Amazon*, 3-5

Figure 2. Historical deforestation and existing land use cover in the Amazon



Data Source: INPE, Project PRODES. Note: Some areas have no data because they had significant cloud cover in satellite imagery, prohibiting land use classification.

Macroeconomic drivers of deforestation

In 1966, the federal government launched an extensive program under the direction of the Superintendency of Development for the Amazon (*Superintendência de Desenvolvimento da Amazônia*, SUDAM) with the stated goal of encouraging economic investment in Amazonia. SUDAM provided huge tax credits to investors, often at negative real rates of interest (between -25% to -35% from 1979-1986).²⁶ While

²⁶ Ibid., 5-6; Joyotee Smith et al., "Dynamics of the Agricultural Frontier in the Amazon and Savannas of Brazil: Analyzing the Impact of Policy and Technology," *Environmental Modeling and Assessment* 3 (1998), 33. Ibid. Moran, *Deforestation and Land use in the Brazilian Amazon*, 1-21

theoretically intended to help landless farmers, SUDAM's subsidy and credit programs were extremely corrupt. Recent investigations have found strong evidence that the majority of credit went primarily to rich outside investors.²⁷ Approved projects could be used to write off 50% of personal and corporate income taxes, which, combined with large subsidies, made investment in the Amazon massively profitable. The majority of SUDAM-financed projects were cattle ranches, which generally practiced unsustainable extensive land use and overgrazing.²⁸ A ban on the international export of Brazilian beef due to hoof-and-mouth disease meant that most of these ranches were not profitable without the extensive subsidies they enjoyed. In the late 1980s, beef prices began to rise, and the lifting of the export ban in 2002 helped to make ranching profitable without extensive subsidies.²⁹ Today, cattle ranching is still a major cause of forest clearing in the Amazon.

Brazil's problematic economy during the 1970s and 1980s also contributed greatly to deforestation. Massive hyperinflation during this period meant that land speculation was extremely profitable. Poor land tenure laws categorized any clearing of land as an "improvement," making deforestation the easiest way to attain a high amount of land. The returns to deforesting even just 14 hectares (ha) of land, holding in for two to three years, and then selling it were more than four times the average wage for farm workers in the rest of Brazil, making clearing an attractive option for the impoverished

²⁷ Lykke E. Andersen and Eustáquio J. Reis, *Deforestation, Development, and Government Policy in the Brazilian Amazon: An Econometric Analysis* (Rio de Janeiro, Brazil: Brazilian Applied Economic Research Institute, 1997), 14.

²⁸ Moran, *Deforestation and Land use in the Brazilian Amazon*, 6

²⁹ Fearnside, *Deforestation in the Brazilian Amazonia: History, Rates, and Consequences*, 682

seeking their fortune.³⁰ Land acquisition feeds into itself, as the profits made from selling the cleared land can be turned into clearing even more, creating a constantly-shifting frontier moving deeper into the Amazon. Some suggest that many “ranches” financed by SUDAM credit during this time had few (if any) cattle, and were actually purchased solely for land speculation.³¹

A country-wide recession during the late 1980s and early 1990s reduced funds available for new investments, but continued hyperinflation maintained land speculation’s importance in driving deforestation. In 1994, the Brazilian government implemented the Real Plan (*Plano Real*), a drastic plan to stabilize the economy and inflation rates, which had reached 2000% in 1993. The Real Plan froze many privately-held assets in Brazilian banks, de-indexed prices, and set a currency ceiling linked to the US dollar.³² Although the Real Plan successfully reduced the profitability of deforestation for land speculation, the resulting economic growth and expansion intensified industrial and agricultural development in the Amazon. In 1995, the deforestation rate hit its peak annual rate of 29,059 km², a massive area the size of Belgium (Figure 1).³³

Land tenure policies as drivers of deforestation

Brazil has been plagued by problematic land tenure policies and social inequality since colonial Portuguese occupation. For the first half of the 20th century, land grants were given almost exclusively to wealthy, influential individuals with the favor of the

³⁰ Moran, *Deforestation and Land use in the Brazilian Amazon*, 7

³¹ Fearnside, *Deforestation in the Brazilian Amazonia: History, Rates, and Consequences*, 681

³² Smith et al., *Dynamics of the Agricultural Frontier in the Amazon and Savannas of Brazil: Analyzing the Impact of Policy and Technology*, 34

³³ "Project PRODES," Brazilian National Institute for Space Research, <http://www.obt.inpe.br/prodes/index.html> (accessed October 30, 2012, 2011).

current government.³⁴ This led to huge inequalities in land ownership; in 1985, the Gini coefficient of land ownership was 0.85, and an estimated 70% of all rural households were landless.³⁵ Popular pressure on the government to provide opportunities for land acquisition has left behind a legacy of policies which fuel violent conflict and incentivize deforestation.

The National Institute for Colonization and Agrarian Reform (*Instituto Nacional de Colonização e Reforma Agrária*, INCRA) was established in 1971 to promote the cause of landless settlers. In its early years, INCRA assisted with the government's goal of developing the Amazon by siting settlements near major highways being constructed in the Amazon. Landless peasants could claim title to an area up to three times what they cleared, and the expanding network of roads through the Amazon continually opened up access to greater areas.³⁶ The oil crises of the 1970s and a subsequent drop in government funding brought an abrupt halt to many colonization programs, with the ambitious goal of moving 100,000 families into the region only 6% complete.³⁷ With many planned roads abandoned, smallholder deforestation in the 1970s and 1980s was concentrated in states near the edges of the Amazon, such as Rondônia and Pará. It is

³⁴ Lee J. Alston, Gary D. Libecap, and Bernardo Mueller, "Land Reform Policies, the Sources of Violent Conflict, and Implications for Deforestation in the Brazilian Amazon," *Journal of Environmental Economics and Management* 39 (2000), 165.

³⁵ The Gini coefficient measures inequality in distribution of wealth by plotting the cumulative percentage of wealth on the cumulative percentage of the population, then calculating the area between this line and the line of equality. A Gini of 0 indicates that all wealth is perfectly distributed; a Gini of 1 indicates that a single individual owns all resources. Smith et al., *Dynamics of the Agricultural Frontier in the Amazon and Savannas of Brazil: Analyzing the Impact of Policy and Technology*, 33

³⁶ Banerjee, Macpherson, and Alavalapati, *Toward a Policy of Sustainable Forest Management in Brazil: A Historical Analysis*, 133; Moran, *Deforestation and Land use in the Brazilian Amazon*, 4-5

³⁷ *Ibid.*, 5

important to that though smallholder deforestation in these states was substantial, it was a minor factor in the Amazon as a whole during this time.³⁸

With the opening of Brazil's military government in 1974 to the gradual implementation of democracy, the forces advocating land reform began to work in earnest.³⁹ Particularly important was the establishment of the Landless Rural Workers' Movement (*Movimento dos Trabalhadores Rurais Sem-Terra*, MST) in 1984. MST and other lobby groups brought the plight of rural workers to national and international attention and gained substantial institutional support from INCRA.⁴⁰

The Federal Constitution of 1988 established many policies which would have a huge impact on deforestation and development in the Amazon. Chief among them was the codifying of a principle that had been in practice for some time: any government or private land could be claimed by anyone who "improved" on it. According to the provisions of the Constitution,

Article 189 – It is up to the Union to expropriate for social interest, for the purpose of agrarian reform, the rural establishment which is not fulfilling its social function...

Article 191 – The social function is fulfilled... by the following requirements:

- a) adequate and rational use;
- b) adequate use of the natural resources available and preservation of the environment;
- c) observance of the dispositions which regulate labor relations;

³⁸ Alston, Libecap, and Mueller, *Land Reform Policies, the Sources of Violent Conflict, and Implications for Deforestation in the Brazilian Amazon*, 164

³⁹ Banerjee, Macpherson, and Alavalapati, *Toward a Policy of Sustainable Forest Management in Brazil: A Historical Analysis*, 134

⁴⁰ Alston, Libecap, and Mueller, *Land Reform Policies, the Sources of Violent Conflict, and Implications for Deforestation in the Brazilian Amazon*, 168

d) exploration which favors the well-being of the proprietors and workers.

Article 196 – One who, not being the proprietor of a rural or urban establishment, possesses as his/her own for five uninterrupted years, without opposition, an area not greater than fifty hectares, making the land productive through his/her labor, or that of his/her family, having in the land their habitation, will acquire the property.⁴¹

Thus, in practice, a squatter can clear an area of land, live on it for five years, and then have legal claim to it, *regardless of the previous ownership status of the land*. Targeted lands typically include government-owned property and forested areas of large landholdings, as these lands are difficult to police and rarely unmonitored. INCRA manages the legal expropriation of occupied land, compensating the affected owners at a level typically below market-value.⁴²

The problem with these provisions becomes exceedingly clear when considered along with environmental regulations which are also in place. Under legal requirements, private landowners in the Legal Amazon are obligated to retain 80% of their property as a “legal reserve” in its original forested state. However, the registration process is costly and bureaucratic, and because the 80% figure represents an increase from the 50% required by the 1965 Forest Code, many landowners are in violation of the law due to deforestation that occurred before the change.⁴³ As a result, few landowners register their legal reserves, which makes these areas easy targets for squatters. In fact, even registered areas are commonly viewed by INCRA as not being under “productive use,”

⁴¹ Ibid., 165

⁴² Ibid., 167

⁴³ Banerjee, Macpherson, and Alavalapati, *Toward a Policy of Sustainable Forest Management in Brazil: A Historical Analysis*, 132

and private holdings have been ceded to squatters despite court orders for their eviction.⁴⁴ Thus, the incentive system currently in place encourages squatters to clear land in order to claim it through expropriation by INCRA, while landowners have an incentive to clear land to show that it is currently being put to “productive use,” thereby protecting it from squatters. Surveys in Pará found that, when faced with the threat of land invasion, landowners would more often clear land beyond legal allowances, even at the risk of substantial fines.⁴⁵

Uncertain land tenure in the Amazon does not just affect environmental well-being, but has a profound human cost as well. Unsurprisingly, relations between landowners and squatters are often confrontational and have led to many violent conflicts in the past few decades. In 1989 alone, an estimated 800 people were killed in land conflicts in the Amazon.⁴⁶ Tragically, this problem persists even today; as recently as March 2012, three rural activists were gunned down in the southern state of Minas Gerais.⁴⁷ These murders are politically embarrassing to the Brazilian government, so it typically acts decisively when it believes conflict is escalating within a region. In 2005, the government deployed 2,000 soldiers to Pará to maintain order after a US missionary and an MST activist were murdered there.⁴⁸

⁴⁴ Alston, Libecap, and Mueller, *Land Reform Policies, the Sources of Violent Conflict, and Implications for Deforestation in the Brazilian Amazon*, 168

⁴⁵ *Ibid.*, 170

⁴⁶ Moran, *Deforestation and Land use in the Brazilian Amazon*, 17

⁴⁷ Bradley Brooks, "Brazil Investigating Killings of 3 Rural Activists," *Associated Press*, March 26, 2012.

⁴⁸ Banerjee, Macpherson, and Alavalapati, *Toward a Policy of Sustainable Forest Management in Brazil: A Historical Analysis*, 145

Simulations by Alston et al. found that efforts by INCRA and the federal government to respond quickly to violence actually had the unintended consequence of *increasing* the number of conflicts.⁴⁹ Because INCRA has limited staff and cannot address all squatter claims, priority typically goes to the places which receive the most public attention, thereby encouraging squatters to instigate violence. Groups such as the MST have used these tactics to their advantage, organizing protests and road blockades to force INCRA to negotiate new policies to benefit landless workers.⁵⁰ This suggests that the sources of violent conflict must be addressed, rather than merely responding to issues as they arise. Little change is likely in the current situation of conflicting policies and uncertain land tenure.

Recent developments and the current state of deforestation

As international concern for the Amazon grew, pressure on the Brazilian government to end problematic policies rose.⁵¹ In 1991, Brazil suspended all SUDAM tax breaks and prohibited further credit subsidies, though any pre-existing projects continued to receive benefits.⁵² Removal of major subsidies for clearing in the Amazon is an important step, but many smaller programs still continue which create incentives for deforestation. Agricultural credit is common in Brazil and carries strong popular support. As in many countries, the Brazilian government will often buy crops at levels above

⁴⁹ Alston, Libecap, and Mueller, *Land Reform Policies, the Sources of Violent Conflict, and Implications for Deforestation in the Brazilian Amazon*, 183

⁵⁰ Banerjee, Macpherson, and Alavalapati, *Toward a Policy of Sustainable Forest Management in Brazil: A Historical Analysis*, 144; Fearnside, *Deforestation in the Brazilian Amazonia: History, Rates, and Consequences*, 685

⁵¹ Moran, *Deforestation and Land use in the Brazilian Amazon*, 10

⁵² Fearnside, *Deforestation in the Brazilian Amazonia: History, Rates, and Consequences*, 681

market price. Set prices for particular crops, irrespective of the location of the farm, remove the naturally-existing incentive to avoid farming in areas far removed from major cities and transportation routes.⁵³ In this way, even areas with poor access to roads are vulnerable.

Due to the success of the Real Plan, Brazil's inflation rate has been fairly stable since the late 1990s, greatly reducing the importance of land speculation in driving deforestation. However, there is still a great amount of money to be earned by purchasing land in locations where roads are slated to be built, as the connection with infrastructure greatly increases the land's value.⁵⁴ In addition, no changes have been made to laws protecting the rights of squatters to claim land by clearing it, nor does this seem likely to occur anytime soon, given that the current regulations are a Constitutional right. Clashes between environmental and social activists divide what would otherwise be a powerful coalition as both groups struggle to find a middle ground on issues such as legal reserve requirements on public land.⁵⁵

As the global price of soybeans has risen, lobbyists for the industry have gained considerable sway with the government, particularly in the Amazon, where soybeans today cover more area than any other crop.⁵⁶ Currently, strong voices are advocating for the construction of roads to link Brazil to the western coast of South America, allowing

⁵³ Ibid., 685

⁵⁴ Ibid., 685

⁵⁵ Dave Gilbert, "Brazil Vote Sparks Fears for Future of Rainforest," *CNN*, March 18, 2012.

⁵⁶ "Municipal Agricultural Production," Brazilian Institute of Geography and Statistics, <http://www.ibge.gov.br/english/estatistica/economia/pam/2010/default.shtm> (accessed February 11, 2012).

soybeans and other crops to be transported to markets in Asia.⁵⁷ As seen before, roads enable access by loggers and farmers to increased areas, and though it has made some efforts to establish protected areas along new roads, the Brazilian government has a poor track record of monitoring these areas for illegal settlements.⁵⁸

One of the major advances made in curbing deforestation is the increased use of remote sensing from satellite technology to monitor deforestation more easily and respond more rapidly. For many years, the Brazilian government delayed the release of deforestation figures for political expediency; for instance, the 1995 peak deforestation rate was not reported publicly until one month after the 1997 Kyoto Conference on Global Warming.⁵⁹ Beginning in 2002, the Brazilian National Institute for Space Research (*Instituto Nacional de Pesquisas Espaciais*, INPE) announced that they will release figures as soon as they are available. A particularly important program is Detection of Deforestation in Real Time (*Detecção de Desmatamento em Tempo Real*, DETER).⁶⁰ DETER uses low-resolution photos taken on a daily basis to monitor for deforestation "hotspots." Although this provides only rough estimates, it has the advantage of allowing quick reactions to detected burning or large-scale clearing, an invaluable tool for local agencies attempting to monitor for deforestation within their jurisdictions.

⁵⁷ Smith et al., *Dynamics of the Agricultural Frontier in the Amazon and Savannas of Brazil: Analyzing the Impact of Policy and Technology*, 34

⁵⁸ Banerjee, Macpherson, and Alavalapati, *Toward a Policy of Sustainable Forest Management in Brazil: A Historical Analysis*, 142; Smith et al., *Dynamics of the Agricultural Frontier in the Amazon and Savannas of Brazil: Analyzing the Impact of Policy and Technology*, 31-46

⁵⁹ Banerjee, Macpherson, and Alavalapati, *Toward a Policy of Sustainable Forest Management in Brazil: A Historical Analysis*, 143

⁶⁰ "Detection of Deforestation in Real Time (DETER)," Brazilian National Institute for Space Research, <http://www.obt.inpe.br/deter/> (accessed October 12, 2011).

Tools such as DETER and its higher-resolution annual counterpart, PRODES, are all the more valuable because of increased interest on the part of state governments to make illegal deforestation a priority. Major crackdowns on illegal logging between 2003 and 2006 resulted in the arrests of 186 people, 63 of whom were government employees who had been taking bribes from loggers to hide their activities.⁶¹ Unfortunately, these gains are relatively small compared to the overall level of unbridled illegal activity. Although fines totaling US\$290 million were issued by the Brazilian Institute of Environment and Renewable Natural Resources (*Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis*, IBAMA) between 2001 and 2004, a scant 2% of this total was collected.⁶² Inadequate resources for enforcement plague most environmental agencies, and in many areas corrupt local officials may tolerate or even encourage exploitation of forest resources. Other problems include selective logging, which is far more difficult to detect than complete clearcutting, but which carries a host of negative impacts that have not been well-studied.⁶³

Despite the many issues driving deforestation, recent years have shown impressive reductions in the rate of deforestation (Figure 1). Statistics released this year reported the lowest deforestation rate since the government began monitoring in 1988 (Figure 1).⁶⁴ This is an impressive accomplishment reflective of the tremendous amount

⁶¹ Banerjee, Macpherson, and Alavalapati, *Toward a Policy of Sustainable Forest Management in Brazil: A Historical Analysis*, 143

⁶² *Ibid.*, 143

⁶³ Jonathan A. Foley et al., "Amazonia Revealed: Forest Degradation and Loss of Ecosystem Goods and Services in the Amazon Basin," *Frontiers in Ecology and the Environment* 5, no. 1 (February, 2007), 26-27.

⁶⁴ *Project PRODES*

of attention given to the problem. However, there is still room for much more progress, and monitoring cannot be effective unless the government continues funding successful programs.

One area of conservation policy that has received substantial international attention is that of markets for environmental services, typically carbon sequestration. Markets which finance preservation of existing forests and reforestation in cleared lands are already being implemented on a small-scale throughout Latin America. The UN program for Reducing Emissions from Deforestation and Degradation (REDD) offers a promising opportunity if the Brazilian government is willing to put in the effort required to manage a REDD project.⁶⁵ Other alternatives include the Clean Development Mechanism under the Kyoto Protocol, which can attract funding for projects which can show that they will reduce CO₂ emissions below levels which would have occurred at baseline.⁶⁶ Despite the opportunities available, the Brazilian government has not actively sought to participate in international markets for environmental services at a large scale.

Protected Areas in Brazil

Although many opportunities exist for encouraging biodiversity conservation, this study will focus primarily on the systems of protected areas within Brazil. This broad category includes many different legally-defined groups, from fully protected ecological research stations to indigenous lands to privately-managed reserves. This section

⁶⁵ Yadvinder Malhi et al., "Climate Change, Deforestation, and the Fate of the Amazon," *Science* 319, no. 169 (January, 2008), 172.

⁶⁶ Fearnside, *Deforestation in the Brazilian Amazonia: History, Rates, and Consequences*, 686

describes each type of protected area and outlines its relevance to the overall development of the protected area system.

Conservation units

In 1959, the first protected area in the Brazilian Amazon was established by the military government in Tocantins.⁶⁷ However, other than this single park, protected areas were not a policy focus, and the tool was abandoned for over a decade. In 1974 through 1989, a variety of NGOs, individual activists, and governmental organizations initiated a landmark process that resulted in the creation of a multitude of national parks, biological reserves, and ecological stations covering an area the size of New England.⁶⁸ Inspired by the success of these early pioneers, a larger coalition was formed in 1989 to assess the potential for new protected areas in the Amazon and deliver recommendations for their establishment. After ten years of work, the National System of Conservation Units (*Sistema Nacional de Unidades de Conservação da Natureza*, SNUC) was created in 2000 to standardize existing regulation, compile a national database of all preserves, and promote their maintenance and expansion.⁶⁹ Although the majority of current CUs are state- or federal- owned, the SNUC recognizes units formed by municipal governments as well.

Under SNUC, conservation units (CUs) are divided into one of two categories.

Integral protection CUs are similar to the system of national parks and reserves found in

⁶⁷ M. A. Pedlowski et al., "Conservation Units: A New Deforestation Frontier in the Amazonian State of Rondônia, Brazil," *Environmental Conservation* 32, no. 2 (2005), 150.

⁶⁸ Russell A. Mittermeier et al., "A Brief History of Biodiversity Conservation in Brazil," *Conservation Biology* 19, no. 3 (June, 2005), 602.

⁶⁹ Pedlowski et al., *Conservation Units: A New Deforestation Frontier in the Amazonian State of Rondônia, Brazil*, 150

the United States; no resources extraction is allowed within their borders, and their sole purpose is conservation of biodiversity. The second category of CU, sustainable use, is an innovative creation that attempts to balance the goals of conservation with the economic realities of poverty and social inequity in Amazonia.⁷⁰ Sustainable use reserves were first implemented in the state of Acre as a tool for protecting the traditional land use rights of local communities whose lands were threatened by the development of roads, ranches, and farms. Depending on the type of sustainable use CU, logging, small-scale farming, and the persistence of settlements may be allowed within its borders.⁷¹ Sustainable use CUs are an important contribution because they enjoy great public support. Unlike integral protection areas, which are viewed as conflicting with the needs of poor rural communities by restricting land use, sustainable use preserves are often embraced and fiercely protected by the people who depend on them for their livelihoods.⁷²

Indigenous lands

Brazil's indigenous population has a rich but conflict-ridden history. Currently, 197 distinct indigenous groups live in Brazilian forests, comprising approximately 0.4% of the population.⁷³ For the majority of the last few centuries, indigenous peoples have been granted few rights and were often the victims of either intentional or collateral harm from colonial settlers. Estimates suggest that today's indigenous population is only

⁷⁰ Ibid., 150

⁷¹ Mittermeier et al., *A Brief History of Biodiversity Conservation in Brazil*, 602

⁷² Ibid., 603

⁷³ *World Directory of Minorities and Indigenous Peoples - Brazil: Overview* (Minority Rights Group International, 2007).

7% of what it once was in 1500. Coordinated massacres by colonists, ranchers, and the military completely exterminated another 87 groups in the 20th century alone.⁷⁴

Only recently have any efforts been made to protect the traditional rights of indigenous groups in Brazil. In 1967, the National Indian Fund (*Fundação Nacional do Índio*, FUNAI) was created and charged with protecting the interests of indigenous groups and registering their ownership of land they traditionally occupied. Early progress was slow and rife with discrimination; only 15% of total indigenous lands were legally ratified from 1973 to 1981.⁷⁵ Public pressure in response to continued murders and land-grabbing eventually forced the government to act, and the total amount of legally-defined indigenous land in 2005 was 16.4% of the Legal Amazon, an area larger than all CUs combined.⁷⁶ Because of the size of land under indigenous ownership, integration of indigenous lands is vital to any large-scale program of biodiversity conservation.

Indigenous reserves are an interesting portion of the system of protected areas because they have very few restrictions on their management. Decisions regarding land use are left primarily to the indigenous leadership, with little to no oversight by governmental agencies.⁷⁷ Because of the lack of regulations, there is significant debate about the role of indigenous people in conservation. The classical portrait of the noble guardian of the forest has persisted for many years, fueled by the international prominence of indigenous activists such as Chico Mendes, the leader of the rubber

⁷⁴ Ibid.

⁷⁵ Bruce Albert, "Indian Lands, Environmental Policy and Military Geopolitics in the Development of the Brazilian Amazon: The Case of the Yanomami," *Development and Change* 23 (1992), 38.

⁷⁶ Mittermeier et al., *A Brief History of Biodiversity Conservation in Brazil*, 603

⁷⁷ D. Nepstad et al., "Inhibition of Amazon Deforestation and Fire by Parks and Indigenous Lands," *Conservation Biology* 20, no. 1 (2006), 67.

tappers movement, which advocated sustainable use of forest resources by indigenous groups and other smallholders.⁷⁸ Today, indigenous groups in many parts of the Amazon work in conjunction with conservationist groups to monitor for land incursions, and groups such as the Kayapó have implemented a sustainable game management system within their lands.⁷⁹ However, other indigenous tribes have been criticized for entering into contracts with major commercial interests to allow massive deforestation or mining on their lands.⁸⁰ Although the debate over whether indigenous groups actually manage their lands sustainably continues, the real conclusion is that indigenous people are neither perfect protectors nor insensitive villains. Rather, like any other group of human beings, they are strongly influenced by economic and social incentives, and policies involving indigenous rights should be considered with this in mind.

Private reserves of natural heritage (RPPNs)

The final category of protected areas is the system of Private Reserves of Natural Heritage (*Reservas Particulares do Patrimônio Natural*, RPPNs). This system, created by IBAMA in 1990, allows private landowners to register their land for permanent protection status. In return, reserves are excluded from some property taxes, and may be prioritized for certain types of sustainability funding.⁸¹ Although RPPNs represent a small fraction of the total protected area in Brazil, they are a key feature in conservation strategies that

⁷⁸ Albert, *Indian Lands, Environmental Policy and Military Geopolitics in the Development of the Brazilian Amazon: The Case of the Yanomami*, 49

⁷⁹ Nepstad et al., *Inhibition of Amazon Deforestation and Fire by Parks and Indigenous Lands*, 71

⁸⁰ Carlos A. Peres, "Indigenous Reserves and Nature Conservation in Amazonian Forests," *Conservation Biology* 8, no. 2 (June, 1994), 586-587.

⁸¹ Bill Hinchberger, "RPPN: Private Reserves Embrace Ecotourism in Brazil," BrazilMax, http://www.brazilmax.com/news3.cfm/tborigem/fe_ecology/id/1 (accessed March 24, 2012).

seek to form biological corridors or between larger, fragmented protected areas. Especially in the Atlantic Forest, where only 9.3% of the total remaining forest is within protected areas, RPPNs provide an important opportunity for future conservation.⁸² Because the designation of an RPPN is completely voluntary, most owners tend to be seriously committed to forest protection; in many cases, RPPNs are better managed than state and federal reserves, and many actively encourage ecotourism and environmental education as a source of revenue.⁸³

Effectiveness and extent of protected areas

Since 2000, international efforts to increase the protected area within the Amazon have intensified. In 2002, the Brazilian government entered into a commitment with the World Bank, the World Wildlife Fund (WWF), and the Global Environmental Facility to triple the amount of protected areas in the Amazon under the Amazon Region Protected Areas program (ARPA).⁸⁴ Currently, 32% of the total forested Amazon is inside protected areas, with the majority in indigenous reservations and state and federal reserves (Figure 3).⁸⁵ In order to avoid land conflicts, most protected areas are established far from the areas where most deforestation occurs.⁸⁶ While this places them under less risk of illegal incursion

⁸² Ribeiro et al., *The Brazilian Atlantic Forest: How Much is Left, and how is the Remaining Forest Distributed? Implications for Conservation*, 1147

⁸³ Mittermeier et al., *A Brief History of Biodiversity Conservation in Brazil*, 602; Hinchberger, *RPPN: Private Reserves Embrace Ecotourism in Brazil*

⁸⁴ Pedlowski et al., *Conservation Units: A New Deforestation Frontier in the Amazonian State of Rondônia, Brazil*, 150

⁸⁵ Britaldo Silveira Soares-Filho et al., "Modelling Conservation in the Amazon Basin," *Nature* 440 (March, 2006), 520.

⁸⁶ Nepstad et al., *Inhibition of Amazon Deforestation and Fire by Parks and Indigenous Lands*, 69-70

Unfortunately, limited governmental resources often mean that there is little monitoring for deforestation or invasion within protected areas. Analysis by the WWF in 1999 found that only 8.4% of CUs were well-managed, and 54.6% were in precarious situation, primarily due to lack of funding.⁸⁷ Pedlowski et al. monitored deforestation in CUs in Rondônia from 1992 through 1999; in these seven years, the total amount of deforested areas increased by 0.7%, a much smaller rate than that outside of protected areas, but a significant amount nonetheless.⁸⁸ The problem of deforestation and CUs is particularly significant in areas that are being considered to be protected in the future – if squatters and loggers are aware of the possibility that land may soon be restricted, they will often act quickly to clear as much as possible before doing so becomes illegal.⁸⁹ In this way, 59.7% of the CUs originally planned in Rondônia were never created, as by the time the bureaucratic procedures were completed, ranchers and colonists had degraded these lands beyond the point where they could be considered for any level of protection.⁹⁰

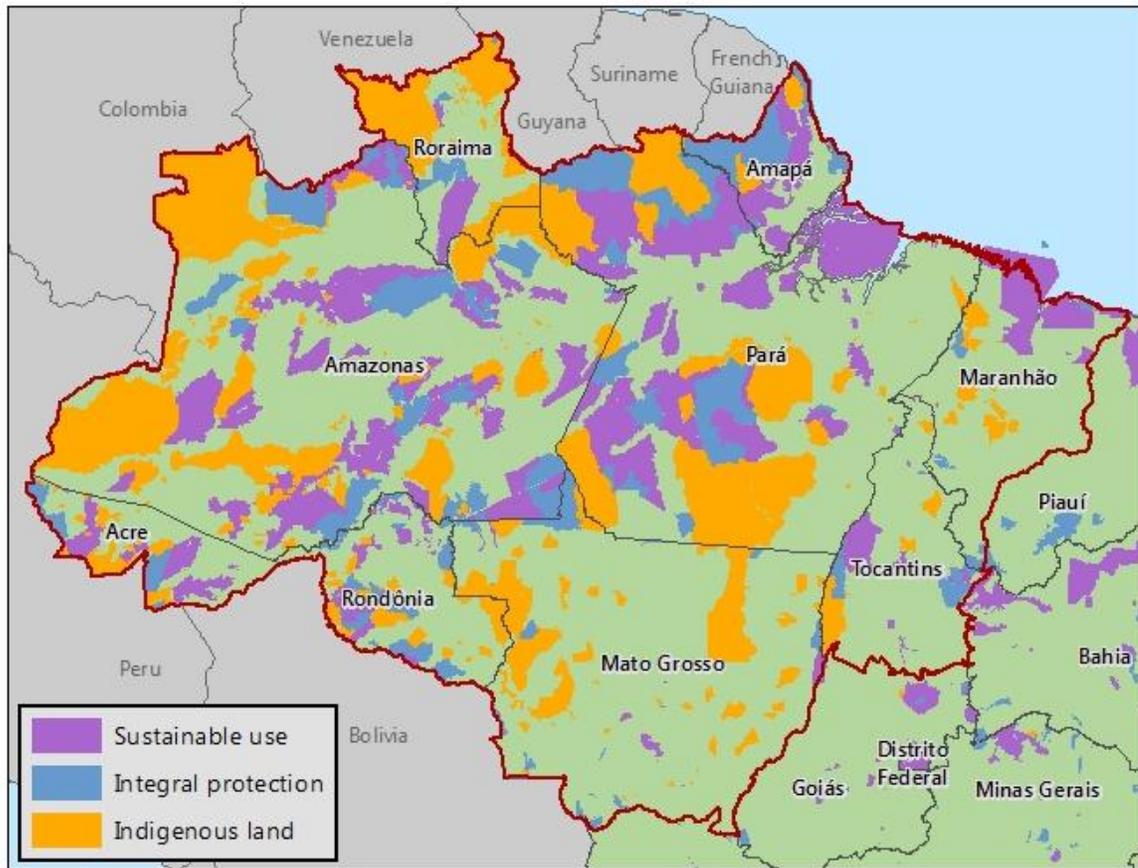
⁸⁷ Wilson Loureiro, "Contribution of the Ecological ICMS to Biodiversity Conservation in the State of Paraná" (Doctorate in Forestry Engineering, Federal University of Paraná, 2002), 20.

⁸⁸ Pedlowski et al., *Conservation Units: A New Deforestation Frontier in the Amazonian State of Rondônia, Brazil*, 152

⁸⁹ Alston, Libecap, and Mueller, *Land Reform Policies, the Sources of Violent Conflict, and Implications for Deforestation in the Brazilian Amazon*, 169

⁹⁰ Pedlowski et al., *Conservation Units: A New Deforestation Frontier in the Amazonian State of Rondônia, Brazil*, 150

Figure 3. Conservation units and indigenous lands within the Amazon



Data Sources: CUs: MMA, Indigenous lands: FUNAI

In some cases, local governments will actively support illegal logging within CUs, particularly if the areas are established by the federal or state government. In these cases, local governments view the protected areas within their borders as an unchosen impediment to their economic growth, and have few incentives to maintain them.⁹¹ The lack of support for CUs at the local level is a major challenge. When combined with poor funding for monitoring and enforcement, even the large areas currently protected face a high risk of deforestation.

⁹¹ Loureiro, *Contribution of the Ecological ICMS to Biodiversity Conservation in the State of Paraná*, 2

Despite these limitations, empirical research has shown that the importance of protected areas as a tool for conservation cannot be overstated. A study by Nepstad et al. found that sustainable use CUs, integral protection CUs, and indigenous lands all served to limit deforestation and fires, with much higher rates of both being found just outside or near the edges of protected areas than inside.⁹² Simulations of deforestation by Soares-Filho et al. under business-as-usual projections suggest that by 2050, 2.1 million km² of the Amazon will be deforested, a reduction to only 53% of the forest's original extent. However, if current goals for increased protected areas are met, then this could reduce total deforestation by 7%, and if the quality of monitoring and enforcement improves in these protected areas as well, then up to 43% of total deforestation could be avoided.⁹³

Clearly, CUs and other protected areas have the possibility to becoming a solid foundation for future environmental protection in Brazil. To increase the usefulness of protected areas, increased monitoring and action against incursions is required.⁹⁴ In addition, better community engagement and local support are vital, as local groups are often the most successful at maintaining areas if they have the incentive to do so.

⁹² Nepstad et al., *Inhibition of Amazon Deforestation and Fire by Parks and Indigenous Lands*, 69

⁹³ Soares-Filho et al., *Modelling Conservation in the Amazon Basin*, 522

⁹⁴ Adalberto Verissimo, Mark A. Cochrane, and Carlos Souza, Jr., "National Forests in the Amazon," *Science* 297 (August 30, 2002), 1478.

The Ecological ICMS

History and Structure of the ICMS

The Tax on Circulation of Goods and Services (*Imposto sobre a Circulação de Mercadorias e Prestação de Serviços de Transporte Interestadual e Intermunicipal e de Comunicação*, ICMS) is the main revenue source for state and local governments in Brazil.⁹⁵ Established by the 1988 Constitution, the ICMS is a value-added tax, meaning that it is applied incrementally to goods at each stage of their production. Any transfer of goods and services, communication, interstate or intrastate transportation, or importation of goods from abroad is subject to the ICMS, with a few exceptions. Petroleum is not taxed, and books and newspapers are excluded as well.⁹⁶ The exact process by which ICMS receipts are calculated and collected is somewhat complicated, but its details are not particularly relevant this study, so I will not discuss them here.

All ICMS funds are collected by the state governments. The Federal Constitution requires that 25% of this total collected is then redistributed to the municipalities within the state. When determining the criteria by which funding is divided amongst municipalities, the Constitution requires that 75% of the funding (18.75% of the total amount at the state level) be passed to municipalities in proportion to where it was collected. Therefore, municipalities which have higher levels of economic activity (higher ICMS returns) will receive a greater share. The remaining 25% of the funds passed to

⁹⁵ Vinicius Duarte Ribeiro, "Ecological ICMS as an Instrument of Forest Policy" (Forestry Engineer, Federal Rural University of Rio De Janeiro, 2008), 2, <http://www.icmsecologico.org.br/images/artigos/a010.pdf> (accessed November 27, 2011).

⁹⁶ *Ibid.*, 2

municipalities (6.25% of the state total) can be distributed according to any criteria chosen by the state government.⁹⁷

It is these final 25% of funds passed to municipalities which provide the state with an opportunity to incentivize policies it wishes to promote. Typical criteria used include area (larger municipalities receive more), population (more populous municipalities receive more), or equality (every municipality receive the same amount). But more innovative policies seek to promote certain behaviors among municipalities. Some states compensate for the amount of agricultural area, for the presence of cultural heritage programs, or for the presence of health services or increased health indicators, such as infant mortality rates.⁹⁸

The subject of this study is a particular type of “policy-promoting” criterion, the “ecological ICMS,” or ICMS-e. ICMS-e policies vary significantly between states, but all share the common cause of promoting environmental well-being. Some states fund municipalities for providing sewage treatment services, for maintaining a local environmental council, or for implementing policies to conserve soil nutrients or to fight fires.⁹⁹ But by far the most common ICMS-e policy compensates municipalities for the amount of protected land within their borders, and it is this type of ICMS-e policy which we will examine in further depth.

⁹⁷ Irene Ring, *Integrating Local Ecological Services into Intergovernmental Fiscal Transfers: The Case of the ICMS-E in Brazil* (Leipzig, Germany: UFZ Department of Economics, 2004), 6-7.

⁹⁸ Loureiro, *Contribution of the Ecological ICMS to Biodiversity Conservation in the State of Paraná*, 49-52

⁹⁹ *Ibid.*, 52

History and structure of the ICMS-e

The ICMS-e was first implemented in the state of Paraná in 1991 with two main goals. The first sought to function as compensation for the lost opportunities for alternative land development by municipalities with significant amounts of protected area within their borders. In some cases, the restrictions placed on municipalities are indeed quite high; for instance, the municipality of Jamarí in Rondônia had a full 55.31% of its total area protected when the ICMS-e was implemented there in 1996.¹⁰⁰ For municipalities such as this, the ICMS-e represents an opportunity for the state government to compensate municipalities for a positive externality which they provide.¹⁰¹ While protected areas serve to maintain biodiversity, capture carbon, and protect watersheds, many of these benefits do not accrue solely to the municipality in which they are located – clearly, many of the above benefits serve not just regional, but also global goals. At the same time, the municipality must bear the full costs of the protected area, as their future opportunities for development are limited, and they may be expected to police and maintain the protected area as well. The ICMS-e seeks to address this externality, thereby increasing local acceptance of and support for protected areas.

¹⁰⁰ Maryanne Grieg-Gran, *Fiscal Incentives for Biodiversity Conservation: The ICMS Ecológico in Brazil* (London, UK: International Institute for Environment and Development: Environmental Economics Programme, 2000), 8.

¹⁰¹ *Ibid.*, 5-6

The second main goal of ICMS-e policies is to not just compensate for existing opportunity costs, but to also incentivize the creation of new protected areas.¹⁰² Simply by allocating a portion of ICMS funds to municipalities with protected areas, the ICMS-e increases the incentive to establish more of them. But, as discussed above, simply having protected areas is not enough to guarantee effective conservation; maintenance and good governance is also vital. To this end, some states have adopted criteria that not only consider the extent of area protected, but also the *quality* of the protected areas.¹⁰³ The methods by which quality is assessed vary from state to state, but generally include such things as the presence of a management plan for the protected area, the hiring of staff to maintain the protected area and monitor for illegal incursions, and the construction of roads and other infrastructure needed to maintain the protected area.

Functioning of the ICMS-e, an example

To better understand the process by which the ICMS-e works, I here outline the method by which the ICMS-e is implemented in the state of Mato Grosso, one of the states of the Legal Amazon, and therefore a part of this study. Although modifications in the criteria were implemented gradually and have changed several times since,¹⁰⁴ this is not important to the general characterization of the ICMS-e itself, so I present here only the current policies.

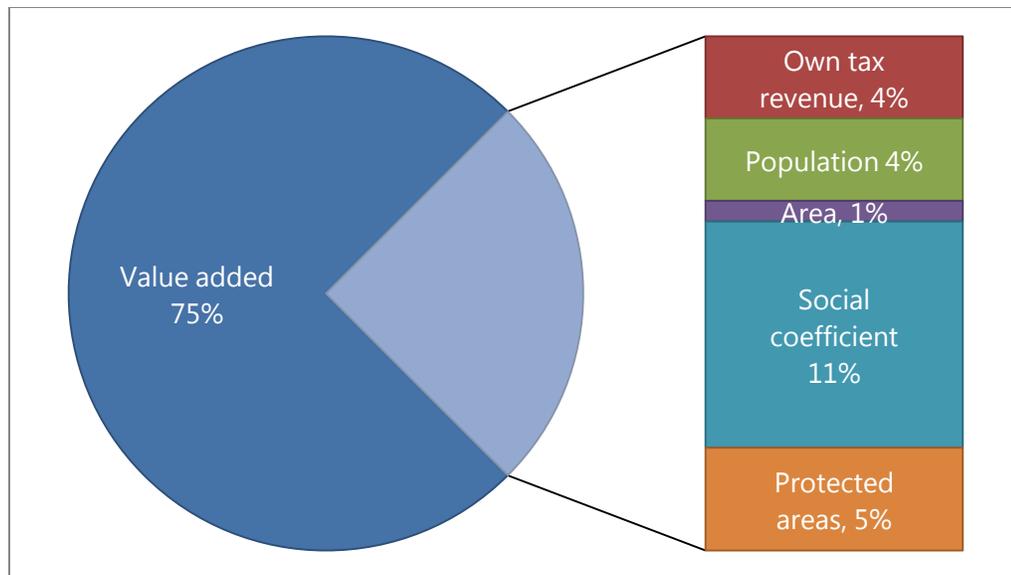
¹⁰² Loureiro, *Contribution of the Ecological ICMS to Biodiversity Conservation in the State of Paraná*, 3

¹⁰³ *Ibid.*, 79-82

¹⁰⁴ "Ecological ICMS," The Nature Conservancy, <http://www.icmsecologico.org.br/> (accessed October 27, 2011).

Distribution of funds in Mato Grosso is determined by 6 different criteria including the legally-mandated value added. The percentages allocated to each are presented in Figure 4. Four percent of ICMS funds are transferred according to the municipality's own tax revenue as a proportion of total taxes collected statewide, four percent of the ICMS funds are distributed in proportion to the population of each municipality, and one percent in proportion to the area of the municipalities. Eleven percent of ICMS funds are distributed based on a coefficient calculated for each municipality which considers several factors of social development and distributes funds to the most impoverished municipalities.

Figure 4. Criteria for determining distribution of ICMS funds to municipalities in Mato Grosso



Data source: Normative Instruction no. 1 of May 5, 2010

In Mato Grosso, 5% of the ICMS funds passed from the state to municipalities are determined by the presence of conservation units and indigenous lands. To qualify, all

protected areas must be registered in the State Register of Protected Areas (*Cadastro Estadual de Unidades de Conservação*, CEUC). RPPNs are allowed to be registered so long as they meet certain criteria showing that they provide environmental education, encourage sustainable production, encourage ecotourism, or otherwise fulfill a greater social benefit. In addition, municipalities wishing to get credit for their protected areas must submit a management plan, have an established fund for financing maintenance of the protected areas, and participate in efforts to solicit community input regarding the protected areas.¹⁰⁵

To calculate the share of ICMS-e funds received by each municipality, the state environmental agency calculates the weight for each municipality using the following equations:¹⁰⁶

$$\text{index}_{PA} = \frac{\text{area}_{PA}}{\text{area}_{muni}} \times \text{type} \times \text{quality} \quad \text{Equation 1}$$

$$\text{index}_{muni} = \sum \text{index}_{PA} \quad \text{Equation 2}$$

$$\text{weight}_{muni} = \frac{\text{index}_{muni}}{\sum \text{index}_{muni}} \quad \text{Equation 3}$$

Equation (1) calculates the index for each protected area, Equation (2) sums the index of all protected areas within a municipality to find the index of the municipality, and Equation (3) scales the index of each municipality by the sum of the indexes of all municipalities within the state. The values of *type* depend on the classification of the protected area or indigenous land; generally, protected areas which place greater restrictions on land use have higher values. Metrics such as this allow the state to

¹⁰⁵ *Normative Instruction no. 1 of May 5, 2010*: State of Mato Grosso.

¹⁰⁶ *Complementary Law no. 73 of December 7, 2000*: State of Mato Grosso, Brazil.

Table 1. Weights of different categories of protected area or indigenous land used to calculate distribution of ICMS-e funds in Mato Grosso

	Category of protected area	Type weight	Minimum and Maximum Quality Scores		
			Municipal	State	Federal
Integral Protection	Biological reserve	1.0	1.0-3.0	1.0-2.0	1.0-2.0
	Ecological station	1.0	1.0-3.0	1.0-2.0	1.0-2.0
	Natural monument	0.8	1.0-5.0	1.0-3.0	1.0-1.5
	Wildlife refuge	0.8	1.0-2.0	1.0-2.0	1.0-1.5
	Parks	0.7	1.0-14.3	1.0-5.0	1.0-3.0
Sustainable Use	Forest	0.5	1.0	1.0-4.0	1.0-1.5
	Indigenous land	0.7	1.0	1.0	1.0-4.0
	Extractive reserve	0.5	1.0	1.0-2.5	1.0-1.5
	Sustainable development reserve	0.5	1.0	1.0	1.0-2.5
	Special protection area	0.5	1.0-2.0	1.0	1.0
	Wildlife reserve	0.4	1.0	1.0-2.0	1.0-1.5
	Area of ecological interest	0.3	1.0	1.0-2.0	1.0
	Park road	0.3	1.0	1.0-2.0	1.0
	Private reserve of natural heritage (RPPN)	0.2	1.0	1.0-20.0	1.0-15.5
	Environmental protection area (APA)	0.2	1.0	1.0-3.0	1.0-2.0
	Quilombolas territories	0.5	1.0	1.0	1.0-2.0

Data Source: Normative Instruction no. 1 of May 5, 2010

encourage the establishment of certain types of protected areas more than others. A particularly innovative part of Mato Grosso's ICMS-e policy is the evaluation of the quality of the protected area when calculating its index. Unlike the systems of other states, which only punish municipalities for decreases in the quality of maintenance, Mato Grosso allows *increases* in a protected area's index if it improves.¹⁰⁷ The maximum amount by which a protected area's quality can increase its index is determined by both the type of the protected area and the level at which it is managed (municipal, state or

¹⁰⁷ Ribeiro, *Ecological ICMS as an Instrument of Forest Policy*, 12

federal). These increases are not insubstantial; RPPNs registered at the state and federal level can have their indexes multiplied by 20 and 15, respectively. Table 1 shows the weights for protected area type and quality of management at each level.

ICMS-e policies in the states of the Legal Amazon

Of the nine states of the Legal Amazon, five have passed ecological ICMS laws as of 2012.¹⁰⁸ Of these five, only four had taken effect in 2009, the last year of the study period. The fifth, Acre, began gradual implementation of ICMS-e in 2010. The types of areas which qualify for consideration in the ecological ICMS vary between states, as do methods of monitoring and enforcement in protected areas. Because these differences provide a unique incentive structure for each state, it is worth understanding what each state's laws entail.

Acre

Acre's ecological ICMS law was passed in 2004, but regulations for its implementation did not follow until 2009, so the effects of Acre's ecological ICMS cannot be assessed in this study.¹⁰⁹ When fully implemented in 2014, Acre will have the highest percentage of its ICMS determined by ecological criteria, at a full 20% of the total funds passed to municipalities out of the 25% possible.¹¹⁰ Areas which are eligible for compensation under Acre's ICMS-e law include indigenous lands; federal, state, and municipal CUs; and RPPNs. The regulating decree for Acre's ecological ICMS law also

¹⁰⁸ *Ecological ICMS*

¹⁰⁹ *Ibid.*; *Law no. 322 of December 23, 1996* State of Amapá, Brazil.

¹¹⁰ *Decree no. 4918 of December 29, 2009*: State of Acre, Brazil.

allows for consideration of other factors when determining distribution between municipalities, including legal reserves on farms, health factors such as infant mortality rates, and quality of schools.¹¹¹ However, these factors are not currently included in the formula used by the environmental ministry for determining the distribution of funds.¹¹² Acre does not have any stipulations regarding quality of management within protected areas, though municipalities must have an environmental ministry to be eligible to participate, and all ecological ICMS funds are earmarked for sustainable development projects or maintenance of protected areas.¹¹³

Amapá

The state of Amapá passed ecological ICMS regulations in 1996 and implemented the program in 1997.¹¹⁴ The ICMS-e was implemented gradually, beginning at 1.1375% of the funds passed to municipalities in 1998, and increasing to 1.4% in 2000. Amapá's program includes federal, state, and municipal CUs, as well as RPPNs and indigenous lands.¹¹⁵ Despite being an earlier program, Amapá's ecological ICMS includes some innovative features. Much like Mato Grosso's policy, different categories of CU are assigned different weights. For instance, CUs in the "integral protection" category, such as ecological stations or biological preserves, are given full weight, while indigenous lands are given only half-weight.¹¹⁶ This method attempts to encourage the establishment of protected areas which fall under the stricter regulations, while still

¹¹¹ Ibid.

¹¹² *Ordinance no. 91 of December 28, 2010*; State of Acre, Brazil.

¹¹³ *Decree no. 4918 of December 29, 2009*

¹¹⁴ *Ecological ICMS*

¹¹⁵ *Law no. 322 of December 23, 1996*

¹¹⁶ Ibid.

allowing some credit for areas which enjoy partial protection only. In addition, when calculating the index of conservation for each municipality, Amapá's ICMS-e uses the quality of management of the protected area in its calculations. Factors considered include the existence of a management plan, infrastructure, the general environmental quality in the protected area, and the presence of financial institutions to support and maintain the protected area.

Mato Grosso

Mato Grosso's ICMS-e law was passed in 2000 and went into effect in 2002, with 5% of the funds passed to municipalities under the ecological criterion.¹¹⁷ More details about Mato Grosso's policies are described above. In the past decade, Mato Grosso has implemented increasingly complex measures of quality in the computation of its ecological ICMS. From the beginning of the program, protected areas which could be shown to have suffered serious environmental degradation would have their contribution to the municipality's share reduced by 50%.¹¹⁸ Further legislation implemented in 2008 added significantly more considerations for the quality of management, as described previously.¹¹⁹ To support these quality evaluations, Mato Grosso maintains an extensive system of state departments dedicated to educating the public about the ecological ICMS, assisting municipalities with the establishment and

¹¹⁷ *Ecological ICMS*

¹¹⁸ *Complementary Law no. 73 of December 7, 2000*

¹¹⁹ *Ecological ICMS: Conserving Mato Grosso's Biodiversity* (Environmental Secretary of State of Mato Grosso, 2009), 1.

management of protected areas, and monitoring environmental quality within protected areas.

Rondônia

Rondônia implemented its ecological ICMS in 1996, setting the percentage of funds determined by this criterion at 5% of the total passed to municipalities.¹²⁰ Because Rondônia's ICMS-e has not been substantially changed since that time, it has the most simplistic regulations of all the states of the Legal Amazon. There is no weighting based on type of protected area and no measurement of quality of the protected area included in the calculations.¹²¹ In addition, Rondônia is the only state within the study area which does not give credit for RPPNs, but only indigenous lands and public protected areas. The legislation does allow for a disqualification of protected areas from a municipality's share if there is evidence of invasion or illegal logging, but as of 2000, this clause had never been used.¹²²

Tocantins

Tocantins gradually implemented an ecological ICMS from 2003 to 2007.¹²³ Interestingly, Tocantins implemented funding based on several criteria of environmental management simultaneously, including not just the presence of protected areas and indigenous lands, but also for the presence of programs to fight fires, maintain basic sanitation, improve soil conservation, and for the existence of municipal environmental

¹²⁰ *Complementary Law no. 147 of January 15, 1996: State of Rondônia, Brazil.*

¹²¹ *Ribeiro, Ecological ICMS as an Instrument of Forest Policy, 1-34*

¹²² *Complementary Law no. 147 of January 15, 1996; Grieg-Gran, Fiscal Incentives for Biodiversity Conservation: The ICMS Ecológico in Brazil, 1-32*

¹²³ *Law no. 1323 of April 4, 2002: State of Tocantins, Brazil.*

agencies.¹²⁴ All together, these programs determined 13% of the total value passed to municipalities, with the portion for protected areas and indigenous lands at 3.5%. These additional programs may help to provide the administrative support for environmental protection both inside and outside protected areas, as well as raise awareness of and funding for various environmental concerns. Tocantins' ecological ICMS includes some fairly basic measurements of quality as well, assessing the presence of infrastructure, a management plan, and whether or not the municipal environmental council is undertaking initiatives to enhance environmental quality within the protected areas.¹²⁵

Evaluating the Effectiveness of the ICMS-e

To date, there have been no statistical or econometric studies of the effectiveness of the ICMS-e. Loureiro presents an in-depth analysis of the impact of the ICMS-e in Paraná, but he does not attempt to control for other variables when concluding that the implementation of the ICMS-e led to an increase in protected areas.¹²⁶ Other authors evaluating the ICMS-e make the same claim, ascribing an increase in protected areas following the implementation of the ICMS-e to its effectiveness.¹²⁷ But because designation of protected areas is permanent, it is extremely unsurprising that the amount of protected area within municipalities increases following the implementation of the ICMS-e; after all, the only other alternative is for the total protected area to remain constant. Given the extent of recent programs designed to increase protected areas in

¹²⁴ Ibid.

¹²⁵ *Ecological ICMS: Technical Orientation Manual* (Nature Institute of Tocantins, 2008), 1.

¹²⁶ Loureiro, *Contribution of the Ecological ICMS to Biodiversity Conservation in the State of Paraná*, 1-189

¹²⁷ Ribeiro, *Ecological ICMS as an Instrument of Forest Policy*, 21-26; Ring, *Integrating Local Ecological Services into Intergovernmental Fiscal Transfers: The Case of the ICMS-E in Brazil*, 14-17

Brazil, it would, in fact, be surprising if protected area *did not* increase following the implementation of ICMS-e policies.¹²⁸ As a result, there is a real need for an evaluation of the ICMS-e which separates its effects from other variables driving the establishment of protected areas, which is what this paper aims to do.

Although they do not offer statistical analysis of its effects, anecdotal reports from interviews with stakeholders in states where the ICMS-e has been implemented suggest that it has at the very least influenced perceptions regarding conservation areas. Several commentators expressed the opinion that the implementation of the ICMS-e made municipal governments stop to assess the protected areas which already existed within their boundaries, viewing these areas as assets for the very first time.¹²⁹ In interviews with municipal mayors, managers of reserves, and other relevant stakeholders, Loureiro found that municipal governments which had previously viewed protected areas as a hindrance to development and maintained antagonistic relationships with CU managers were now more open to the establishment and growth of protected areas within their borders.¹³⁰ Even if the ICMS did not *directly* lead to a greater number of protected areas, even just the government signal that conservation is a worthwhile issue is a great accomplishment. In this way, the ICMS-e serves an important public relations function. By internalizing the positive externalities generated by protected areas, the ICMS-e has increased acceptance of protected areas by rewarding those who have them and signaling to those who don't that doing so would be beneficial. In addition, the

¹²⁸ Veríssimo, Cochrane, and Souza, *National Forests in the Amazon*, 1478

¹²⁹ Grieg-Gran, *Fiscal Incentives for Biodiversity Conservation: The ICMS Ecológico in Brazil*, 26

¹³⁰ Loureiro, *Contribution of the Ecological ICMS to Biodiversity Conservation in the State of Paraná*, 128-130

ICMS-e has spread awareness of the existence and functioning of protected areas, hopefully leading to better, more informed decisions in the future.

In many cases, the ICMS-e has not just opened municipal government's eyes to CUs, but has raised public awareness of the importance of biodiversity conservation as well. In some states, such as Mato Grosso, the ICMS-e legislation itself requires municipalities to engage in education initiatives to obtain any ICMS-e funds, so these policies would clearly result in increased community awareness.¹³¹ In others, however, the effect is more indirect, and must be initiated at the municipal level, as there is little leadership from the state government.(Grieg-Gran 2000, 1-32)

Implementation of the ICMS-e by state governments requires extensive institutional organization. Monitoring the number and quality of protected areas is no small task, especially if the quality monitoring is comprehensive. As a result, the process of administering the ICMS-e will likely strengthen the skills and knowledge of professionals working within state environmental agencies.¹³² In Paraná, local governments enter into terms of agreement with CU managers, pledging increased support and assistance for the protected area in order to maintain their newly-acquired source of revenue.¹³³ Increases in public-private partnerships form strong foundations for future conservation efforts, especially if current agreements are held. In this way, the ICMS-e forms a coalition between municipal leaders and the owners/managers of

¹³¹ *Normative Instruction no. 1 of May 5, 2010*

¹³² Grieg-Gran, *Fiscal Incentives for Biodiversity Conservation: The ICMS Ecológico in Brazil*, 29

¹³³ Loureiro, *Contribution of the Ecological ICMS to Biodiversity Conservation in the State of Paraná*, 114-116

protected areas; where before the groups were antagonistic, they can now help each other in mutually beneficial ways.¹³⁴

¹³⁴ Ibid., 112-114

CHAPTER III. MODEL AND METHODS

Estimation Model

No reviewed literature evaluated the determinants of establishing protected areas directly. This may be because there is no single actor whose incentives can be evaluated; instead, protected areas can be public or private, indigenous lands, and can be established at all three levels of government. As a result, it is not easy to find a single model that captures the many motivating factors leading to the establishment of protected areas.

My approach to dealing with this problem is to model the drivers behind establishing protected areas indirectly by focusing on the demand for land. Because creation of a protected area constrains alternative land uses, it represents a significant opportunity cost for the owner and potential future users of the land. I based my model around the idea that factors which increase demand for land will drive up the opportunity cost of creating new protected areas, thereby decreasing the likelihood that they will be established. This approach has the advantage of a greater treatment in the literature – while few, if any, studies model the establishment of protected areas, a great many model the demand for land.¹³⁵

¹³⁵ For instance, see Kenneth M. Chomitz and Timothy S. Thomas, "Determinants of Land use in Amazônia: A Fine-Scale Spatial Analysis," *American Journal of Agricultural Economics* 85, no. 4 (November, 2003), 1016. or Joyotee Smith et al., "Dynamics of the Agricultural Frontier in the Amazon and Savannas of Brazil: Analyzing the Impact of Policy and Technology," *Environmental Modeling and Assessment* 3 (1998), 31.

Factors affecting the demand for land in the Amazon

Historically, land use change in the Amazon has been driven by a multitude of factors, many of which were discussed in the preceding section. Because ICMS-e funds are distributed at the municipal level, it makes sense to consider the motivations of municipalities in either establishing protected areas themselves or supporting others' efforts to do so. Municipal governments in the Amazon are generally responsive to local social pressures, especially if they are part of an organized movement or if they represent important economic interests.¹³⁶ As a result, government decision-making will likely lean either towards what seems most socially acceptable and politically feasible, or towards what seems most profitable to either independent government agents or the region as a whole.

If there is significant local support for environmental causes, then this alone might be enough to cause governments to create new protected areas, even if doing so precludes more lucrative economic uses of the land. However, with a few exceptions, grassroots movements in Brazil have not placed much emphasis on environmental issues, while still others advocate policies which are actively detrimental to conservation. For instance, landless workers groups have advocated intensely for the opening of more areas for settlement, and would generally oppose any efforts to limit their ability to expropriate land.¹³⁷ In the past, indigenous groups such as the Rubber Tappers

¹³⁶ Onil Banerjee, Alexander J. Macpherson, and Janaki Alavalapati, "Toward a Policy of Sustainable Forest Management in Brazil: A Historical Analysis," *The Journal of Environmental Development* 18 (2009), 143-144.

¹³⁷ Bruce Albert, "Indian Lands, Environmental Policy and Military Geopolitics in the Development of the Brazilian Amazon: The Case of the Yanomami," *Development and Change* 23 (1992), 168.

Movement have brought international attention to the Amazon by campaigning for opportunities for settlement while simultaneously advocating sustainable practices.¹³⁸ In this case, social pressures would incentivize the creating of sustainable use areas, as well as the registration of indigenous reserves.

The clear economic powers with significant land interests in the Brazilian Amazon are large-scale ranchers and farmers. Both of these groups have strong reasons to oppose any protected areas, which limit the available amount of land, thereby driving up land prices. Ranchers in particular typically practice extensive methods which use land inefficiently, as much of the Amazon is poor pasture for cattle.¹³⁹ As a result, ranchers have strong incentives to not only clear the mandated 80% of their property that is a legal reserve, but to also oppose any efforts to limit future land acquisition in the area.

In recent years, the international market for soybeans has helped make the soybean farmers in the Amazon extremely wealthy and influential.¹⁴⁰ Soy is a land-intensive crop, but, more importantly, it is strongly dependent on low transportation costs.¹⁴¹ Soybean farmers have successfully lobbied the government for more and improved roads throughout the Amazon to allow them to more easily export their crops

¹³⁸ Emilio F. Moran, "Deforestation and Land use in the Brazilian Amazon," *Human Ecology* 21, no. 1 (1993), 10.

¹³⁹ Marcos A. Pedlowski et al., "Patterns and Impacts of Deforestation in Rondônia, Brazil," *Landscape and Urban Planning* 38 (1997), 153.

¹⁴⁰ Smith et al., *Dynamics of the Agricultural Frontier in the Amazon and Savannas of Brazil: Analyzing the Impact of Policy and Technology*, 45

¹⁴¹ Philip M. Fearnside, "Deforestation in the Brazilian Amazonia: History, Rates, and Consequences," *Conservation Biology* 19, no. 3 (June, 2005), 682.

internationally.¹⁴² While the direct effect of increased soy farming on demand for land may be positive, the indirect effect of road building which typically accompanies soy farming is likely to be even more significant. As discussed in the previous chapter, roads are a key feature in increasing deforestation and demand for land, allowing access by farmers, settlers, ranchers, and loggers.¹⁴³

In many models of deforestation, increased population or population density is found to increase demand for land.¹⁴⁴ Simply put, more people mean more people who want land. However, the composition of increased population is important; while increased rural populations will directly impact the demand for land, urban populations have minimal land demands.¹⁴⁵ Therefore, it is important to control for the rural/urban makeup when evaluating the impact of population.

A final variable which is important to consider is the impact of increased wealth. Like population, the distribution of wealth is important – many impoverished people may appear to be identical to that of a few relatively wealthy persons at a gross level, but the effects of these two populations would be substantially different. In general, greater economic prosperity allows for investment in machinery that promotes land-intensive farming practices, or increase opportunities for employment outside of the agricultural

¹⁴² Andrea Cattaneo, "Deforestation in the Brazilian Amazon: Comparing the Impacts of Macroeconomic Shocks, Land Tenure, and Technological Change," *Land Economics* 77, no. 2 (May, 2001), 229-230.

¹⁴³ Arild Angelsen and David Kaimowitz, "Rethinking the Causes of Deforestation: Lessons from Economic Models," *The World Bank Research Observer* 14, no. 1 (February, 1999), 85.

¹⁴⁴ *Ibid.*, 87-89

¹⁴⁵ Lykke E. Andersen and Eustáquio J. Reis, *Deforestation, Development, and Government Policy in the Brazilian Amazon: An Econometric Analysis* (Rio de Janeiro, Brazil: Brazilian Applied Economic Research Institute, 1997), 2.

sector.¹⁴⁶ Both of these changes would negatively impact the demand for land, suggesting that an increase in economic well-being would be correlated with increased protected area.

Model description

In all regressions of this study, I used fixed effects evaluation of panel data. Fixed effects is a useful tool here because it can control for time-invariant features present in each group of the panel – in this case, the municipalities. Fixed effects estimation takes the mean of the dependent and each independent variable over time. These means are then subtracted from the variable at each time period in a process called time-demeaning.¹⁴⁷ Equation (4) shows the original estimation model used for the fixed effects regression.

$$\ln(\text{protectedarea})_{it} = \theta + \beta_1 \text{ICMSe}_{it} + a_i + u_{it} \quad \text{Equation 4}$$

The important feature of fixed effects is the fact that any variables which are constant across time will have a value of zero after they are demeaned, as their values are always identical to the mean. These entity-specific fixed effects are shown in Equation (4) as a_i alone; in reality, there would be as many entity fixed effects as there are municipalities. The benefit of time-demeaning is that it controls for variance in the dependent variable that is due to differences across the data set. In this case, it is not hard to imagine that municipalities might have different histories of conservation,

¹⁴⁶ Angelsen and Kaimowitz, *Rethinking the Causes of Deforestation: Lessons from Economic Models*, 89

¹⁴⁷ Jeffrey M. Wooldridge, "Advanced Panel Data Methods," in *Introductory Econometrics: A Modern Approach*, 4th ed. (Mason, OH: South-Western, 2009), 482.

societal makeups, or NGO and other institutional presences which would lead them to have differentiated levels of protected area. With fixed effects, these municipality-specific constants are eliminated, allowing for a more efficient estimation of the effects of the included explanatory variables.

An alternative specification controls for the fixed effects due to the year by adding year dummies which change the intercept of the regression. This is done with using Equation (5). Year-specific effects should only be included if they are jointly statistically significant.

$$\ln(\text{protectedarea})_{it} = \theta + \lambda_1 y2000 + \dots + \lambda_{10} y2009 + \beta_1 \text{ICMSe}_{it} + a_i + u_{it}$$

Equation 5

Study Area and Time Period

The study area used was the government-defined Legal Amazon, an area consisting of nine Brazilian states.¹⁴⁸ Although technically the entire state of Maranhão is not included within the boundaries of the Legal Amazon, its complete area is included in this study. The Legal Amazon is primarily a rural region with an agricultural-based economy and the majority of its area is dominated by tropical moist forests.¹⁴⁹ Ecological issues in the Amazon have been more thoroughly researched than in other ecosystems

¹⁴⁸ "Download Spatial Data," Brazilian Ministry of the Environment, <http://mapas.mma.gov.br/i3geo/datadownload.htm> (accessed October 26, 2011).

¹⁴⁹ This is not to say that there are no differences within the area, as especially the regions in the east and south are more densely-populated and dominated by grasslands. However, the majority of the area has a similar history and demographic and ecological makeup. Smith et al., *Dynamics of the Agricultural Frontier in the Amazon and Savannas of Brazil: Analyzing the Impact of Policy and Technology*, 31-33

of Brazil due to its importance in regional and global climate and biodiversity.¹⁵⁰ The panel data set includes a total of 807 municipalities within these nine states. Data were collected for as many years as were possible. The years 1999 through 2009 were chosen as the target time frame, as this was the extent of economic data such as GDP and Gini coefficients available, and because demographic data are difficult to obtain for years prior to 2000.

Data Sources

Most data were obtained from Brazilian government websites, primarily the Brazilian Institute of Geography and Statistics (*Instituto Brasileiro de Geografia e Estatística*, IBGE). A key feature of my analysis was the use of Geographic Information Systems (GIS) data. Using GIS maps allowed me to obtain information that is not available and to make spatially-explicit connections between existing data. Following is a discussion of the sources of the data used in the study and the calculations and assumptions that were made in order to use the data within my model.

Municipality Areas

The borders of many municipalities changed within the study period, often several times, and occasionally by large amounts. Some of this is due to poor data quality; because many of the municipalities are located within sparsely-inhabited regions of the Amazon, precise definitions of the municipal borders were not possible for many years. In other instances, territorial disputes or changes in the number of municipalities

¹⁵⁰ Russell A. Mittermeier et al., "A Brief History of Biodiversity Conservation in Brazil," *Conservation Biology* 19, no. 3 (June, 2005), 601.

within the state resulted in redefinition of pre-existing boundaries. To include these changes in my analysis, I obtained GIS layers of the municipal borders for as many years as were available. Newly created municipalities are included in the analysis beginning in the year in which they were created.

IBGE offers vector-format files for the years 2001, 2005, and 2007, while the Brazilian Ministry of the Environment (MMA) offers files for the years 2001 and 2005.¹⁵¹ The MMA cites the IBGE as the source for its data, but offers a higher spatial resolution for the 2001 data than is available for download from IBGE. As a result, I used the 2001 layer from the MMA and the 2005 and 2007 layers from IBGE.

Because the panel data requires values for each year, except when otherwise noted, I used a linear transformation to calculate the changes in municipality area in years between the available layers. Thus, for instance, the municipality areas for 2006 were calculated to be the sum of the 2005 area and half the difference between the 2005 and 2007 areas. Because data prior to 2001 and after 2007 was unavailable, I assumed that all states had the same borders in 1999-2000 as in 2001, and that 2007 borders remained unchanged in 2008-2009.¹⁵²

During the study period, the state of Mato Grosso created new municipalities twice, in 2001 and 2005.¹⁵³ This was done by dividing up the areas of previously-existing municipalities into multiple new ones, changing not only the borders of the new

¹⁵¹ "Topographic Mapping Products," Brazilian Institute of Geography and Statistics, http://www.ibge.gov.br/english/geociencias/cartografia/default_topo_int.shtm (accessed October 26, 2011).; *Download Spatial Data*

¹⁵² There were some exceptions to this assumption; these are discussed below.

¹⁵³ Ibid.

municipalities, but also reducing the area of some that had previously existed. Thirteen municipalities were created in 2001, which resulted in border changes for fifteen municipalities that already existed. The 2001 layer of data depicts modified municipalities in their reduced borders, but does not label or divide the area that would become the thirteen new municipalities. As a result, area data for the new municipalities was taken from the 2005 layer, and assumed to have been constant from 2001-2005. For municipalities which had modified borders in 2001, no area data was included for 1999-2000, as here was no clear way to determine their previous full extent. Two new municipalities were created in 2005 from within the borders of two other previously-existing municipalities. Because their area changes were known to be due to the creation of new municipalities, which definitively happened in 2005, the municipalities modified in 2005 were assigned a sudden transition in area from their 2001 extent to their 2005 extent rather than the linear change which was assumed for all other municipalities. While municipalities within other states showed at times significant border changes between the three years of data, no new municipalities were created in states other than Mato Grosso.

Protected Areas

For the purpose of this study, protected areas included all conservation units (*unidades de conservação, CUs*) that are registered within the National System of Conservation Units (SNUC). This includes areas managed at the federal, state, and municipal level, as well as CUs within both the integral protection and sustainable use

categories. All GIS data on CUs were obtained from the MMA.¹⁵⁴ Because every state which uses an ecological ICMS also considers the presence of indigenous lands (*terras indígenas*) when calculating funding distributions, these were considered “protected areas” as well. Data on indigenous territories were obtained from the National Foundation for Indians (FUNAI).¹⁵⁵

ESRI ArcMap was used to calculate the total protected area within each municipality for each year. A protected area was first included in a municipality’s total in the year in which it was registered in the SNUC (in the case of CUs), or in the year in which it was first registered with FUNAI (in the case of indigenous land). Though these areas may have been formed prior to their registration at the national level, my assumption was nonetheless acceptable because most ICMS-e programs do not recognize protected areas that are not registered at either the national or state level.

For all municipalities, any protected area created within their borders prior to the study period (1998 or earlier) was counted in their total for the beginning of the study period. Municipalities which had modified borders in 2001 had no data for the period of 1999-2000, as it is unknown what their original extent was, so they may have had significantly more protected area than suggested by available data. Any protected areas created prior to 2001 within the post-2001 borders of these counties were counted beginning in 2001. Because the 2001 layer did not contain boundary information for newly-created municipalities, I assumed that these counties maintained the same

¹⁵⁴ Ibid.

¹⁵⁵ "Overall Coordination of GIS," Brazilian National Foundation for Indians, <http://mapas.funai.gov.br/> (accessed March 3, 2012).

borders in 2001-2004 as they were depicted in the 2005 layer. Other than the exceptions noted above, a protected area was counted as within the borders of a municipality if it was within its 2001 borders for the period of 1999-2004, if it was within its 2005 borders for the period of 2005-2006, and if it was within its 2007 borders for the period of 2007-2009.

Population and Demographics

Population data for the entire study period came from IBGE. For the year 2000, population figures are from the census, and for the year 2007, population figures are from the national population count.¹⁵⁶ For all other years (Anonymous2011d), population figures are estimates by IBGE.¹⁵⁷

Detailed demographic data at the municipal level was only available in census years (2000 and 2010). I calculated the rural population percentage for each municipality by taking the rural population in 2000 and 2010 as a percentage of the total population. I then used a linear transformation for the intervening years, assuming that the *percentage* (not numerical values) of the rural population changed steadily during the period from 2001-2009. I used the same procedure to find the indigenous percentage of the population in each year.

¹⁵⁶ "2000 Census," Brazilian Institute of Geography and Statistics, http://www.ibge.gov.br/english/estatistica/populacao/default_censo_2000.shtm (accessed January 8, 2012).; "Population Count 2007," Brazilian Institute of Geography and Statistics, <http://www.ibge.gov.br/english/estatistica/populacao/contagem2007/default.shtm> (accessed January 8, 2012).

¹⁵⁷ "Population Estimates," Brazilian Institute of Geography and Statistics, <http://www.ibge.gov.br/english/estatistica/populacao/estimativa2009/default.shtm> (accessed January 8, 2012).

To find demographic information for the year 1999, I turned to the 1996 population count, which, unlike its 2007 counterpart, presented some demographic data at the municipal level.¹⁵⁸ No racial data was available, so no municipality has information on the indigenous composition of its population for the year 1999. The 1996 population count did, however, provide information on the number of rural and urban households within a municipality. Using this, I calculated a linear transition in the rural percentage of the population from 1996 to 2000, which enabled me to have a value for the 1999 rural population.

Municipalities created in 2001 and 2005 were not included in the 2000 census. As a result, I could not perform the linear calculations of either indigenous or rural populations, so for all newly-created municipalities, this demographic data is missing for all years. In addition, the states of Rondônia, Roraima, Pará, Amapá, Tocantins, Maranhão, and Mato Grosso all created new municipalities in the period from 1996-1999. These 140 municipalities have no data for rural population in the year 1999, as they are not present in the 1996 population count.

Economic Variables

The IBGE provides annual estimates of the gross domestic product (GDP) of municipalities for 1999-2009.¹⁵⁹ These are reported in thousand current (2012) Brazilian reais. Per capita GDP was calculated by dividing the municipal-level data by the

¹⁵⁸ "Population Count 1996," Brazilian Institute of Geography and Statistics, <http://www.ibge.gov.br/english/estatistica/populacao/contagem/default.shtm> (accessed February 11, 2012).

¹⁵⁹ "Gross Domestic Product of Municipalities," Brazilian Institute of Geography and Statistics, http://www.ibge.gov.br/english/estatistica/economia/pibmunicipios/2005_2009/default.shtm (accessed October 26, 2011).

population for that year. Gini coefficients are provided by IBGE at the state level.¹⁶⁰

Therefore, they measure the division of *state-level* GDP amongst the entire state population. The gross annual value added was also collected at the state level from IBGE.¹⁶¹

Agriculture

I collected two types of agricultural data, both provided by IBGE. The first measures the planted area of land (in hectares) of permanent and temporary agricultural production, and comes from the annual survey of municipal agricultural production.¹⁶² Permanent agriculture includes such things as coffee, cocoa, oranges, bananas, rubber, and agave. Temporary agriculture (sometimes called annual or shifting agriculture) is predominated by soybeans, with other major crops including rice, sugar cane, corn, beans, and wheat. In general, area of temporary agriculture is much larger than the area of permanent agriculture in the Amazon.

The second measure of agricultural data looked at livestock, particularly cattle. Ideally, a measure of the amount of pasture would be used, but as this was not available at the municipal level, I instead used information on the number of cattle and other

¹⁶⁰ Ibid.

¹⁶¹ "Regional Accounts of Brazil," Brazilian Institute of Geography and Statistics, <http://www.ibge.gov.br/english/estatistica/economia/contasregionais/2009/default.shtm> (accessed April 9, 2012).

¹⁶² "Municipal Agricultural Production," Brazilian Institute of Geography and Statistics, <http://www.ibge.gov.br/english/estatistica/economia/pam/2010/default.shtm> (accessed February 11, 2012).

livestock, including sheep, pigs, and goats. All livestock information was taken from the IBGE's annual municipal livestock survey.¹⁶³

Climate and Topography

Because some previous studies linked climactic data with land use, I also included one climactic variable: annual rainfall. This data was collected in GIS form from the collection of Environmental Variables for Modeling the Distribution of Species (AMBDATA), maintained by the Image Processing Division (DPI) of the National Institute of Space Research (INPE).¹⁶⁴ A raster grid of the average total annual rainfall from 1950-2000, in mm, was used to calculate the mean annual rainfall in each municipality. Each of the three municipality border layers (2001, 2005, and 2007) was used so that despite changes in municipality borders, whether due to the creation of new municipalities or because of minor modification to the borders due to territorial disputes, annual rainfall statistics reflect the updated municipality area. The assumptions used in these calculations are the same as those used for calculating protected area within each municipality.

Log Transformations

Much of the data was transformed using the natural log of the values in order to obtain easily interpretable coefficients. Any missing data (for reasons discussed above)

¹⁶³ "Municipal Livestock Survey," Brazilian Institute of Geography and Statistics, <http://www.ibge.gov.br/english/estatistica/economia/ppm/2010/default.shtm> (accessed March 5, 2012).

¹⁶⁴ "Environmental Variables for Modeling the Distribution of Species," Brazilian National Institute of Space Research, Image Processing Division, <http://www.dpi.inpe.br/Ambdata/index.php> (accessed October 24, 2011).

remained missing after the log transformation. Data values of zero or less than one would return uninterpretable negative values after log transformation, so their log values were set to zero.

Data Analysis

All statistical analysis was performed using STATA. I used a fixed-effects model with robust standard errors to control for heteroskedasticity and correlation between variables.

The dependent variable for all regressions was the natural log of the area of land protected within each municipality expressed in square kilometers. Two forms of the main independent variable were used. The first, a continuous value, was the percentage of each state's ICMS that was determined based on the area protected within each municipality. The second was a set of two dummy variables set to 1 for the presence and 0 for the absence of one of two different categories of ICMS-e policy. ICMS-e area only captures ICMS-e policies which do not monitor for the quality of protected area when determining distribution of ICMS-e funds, while ICMS-e quality describes those that do. These dummies were chosen because they represent the two main "categories" of ICMS-e policies. In states which do not monitor for quality of protected areas, municipalities can receive funding for establishing mere "paper parks," which have no real monitoring or management, and are often subject to invasion and deforestation.¹⁶⁵ On the other hand, ICMS-e policies which monitor for quality incentivize maintenance, but increase

¹⁶⁵ Banerjee, Macpherson, and Alavalapati, *Toward a Policy of Sustainable Forest Management in Brazil: A Historical Analysis*, 135-136

the cost of establishing a park with the implicit assumption that funding for maintenance will be required indefinitely. This suggests that ICMS-e policies which do not monitor for quality are likely to have a larger impact on the total area protected, but may be poorly maintained in comparison.

Various models were tested with many different combinations of explanatory variables. I first regressed the ICMS-e percentage and dummies alone on the log-transformed protected area in order to assess whether the policy had an effect before controlling for other variables. Adding dummy variables for each year to control for both municipality and year fixed effects showed strong joint significance (P-value = 0.0000), so I included these dummies in many of the following regressions.

Next, I tested for significance of each explanatory variable by regressing the ICMS-e percentage and dummies with each other explanatory variable alone on the protected area. All variables that were significant in the above tests were combined into a single regression to test whether they remained significant together.

Using information from the literature review, I tested the combination of variables I believed would have the strongest effect on the amount of protected area. Because I used fixed effects, any variables which changed very little over the study period would not contribute to explaining the variation, as they are mostly captured in the eliminated fixed effects.¹⁶⁶ For this reason, I did not include the area of the municipality or the annual rainfall in this expanded model. Literature suggests that cattle ranching, soybean

¹⁶⁶ Robert Yaffee, "A Primer for Panel Data Analysis," New York University Information Technology Services, http://www.nyu.edu/its/pubs/connect/fall03/yaffee_primer.html (accessed April 1, 2012).

production, and smallholder farming are the main agricultural drivers of deforestation in the Brazilian Amazon, so I included these along with demographic variables.

CHAPTER IV. RESULTS AND DISCUSSION

Summary Statistics

Table 2. Summary statistics of level dependent and independent variables

Variable	Mean	Median	Standard deviation	Minimum	Maximum
area protected (km ²)	15,146	794	34,331	0	318,291
change in area protected (km ²)	145	0	1,829	0	90,705
ICMS-e percentage	1.26	0	2.01	0	5
population	28,321	12,919	88,703	711	1,738,641
per capita GDP (current R\$)	5,715	3,570	7,999	640	131,070
Gini coefficient	0.719	0.708	0.062	0.607	0.895
value added (current million R\$)	15,167	10,916	13,670	1,478	52,777
area (km ²)	6,368	2,097	13,551	65	160,773
area of permanent agriculture (ha)	810	120	2,190	0	30,487
area of temporary agriculture (ha)	13,108	3,150	46,682	0	847,869
head of cattle	79,315	32,976	121,581	0	1,912,009
number of other livestock	11,174	6,721	14,841	0	269,195
population living in rural households (percent)	45.93	47.44	20.12	0.24	98.44
indigenous population (percent)	2.20	0.17	7.44	0	86.77
average annual rainfall (mm)	1,881	1,817	405	1,051	3,362

Note: Value added was summarized at the state, not municipality level

From the summary statistics (Table 2), it is clear that there is a wide variation in the area protected per municipality. Over half of municipalities had protected areas during the study period, though the data is significantly right-skewed. Population and GDP in the Legal Amazon are generally low, though there are some notable exceptions to this norm. Gini coefficients were relatively high. The median municipality had approximately half of its population living in rural households, though municipalities with

larger populations tend to be more urban. Areas of temporary agriculture outnumber areas of permanent agriculture to a great extent, and the number of cattle predominate the number of all other livestock combined.(Smith and others 1998, 31-46)

Regressions

Throughout this analysis, I used two different representations of the ICMS-e policy: the percentage of ICMS funds that are distributed along ecological criteria (ICMS-e percentage) and two dummy variables indicating the presence an ICMS-e policy based on total protected area alone (ICMS-e area only) and the presence of an ICMS-e policy which also monitors for quality in protected areas (ICMS-e quality).

I first performed a simple fixed effects regression with each ICMS-e specification (Table 3, regressions 1 and 2). Dummy variables for each year of analysis were jointly significant (P-value = 0.0000), so I also regressed each ICMS-e specification with year dummies (Table 3, regressions 3 and 4).

Table 3. ICMS-e regressed on log-transformed area protected with municipality and both year and municipality fixed effects

Dependent variable: ln(Area protected)					
Explanatory Variable	ICMS-e alone		With year dummies		
	(1)	(2)	(3)	(4)	
ICMS-e percentage	0.052***	[0.011]	-0.035**	[0.015]	
ICMS-e area only dummy		0.184***		-0.063	[0.058]
ICMS-e quality dummy		0.282***		-0.102	[0.081]
year 2000 dummy			0.033**	[0.014]	0.033** [0.014]
year 2001 dummy			0.084***	[0.024]	0.086*** [0.024]
year 2002 dummy			0.249***	[0.042]	0.233*** [0.041]
year 2003 dummy			0.267***	[0.044]	0.255*** [0.046]
year 2004 dummy			0.316***	[0.052]	0.309*** [0.054]
year 2005 dummy			0.393***	[0.060]	0.382*** [0.061]
year 2006 dummy			0.446***	[0.064]	0.432*** [0.064]
year 2007 dummy			0.476***	[0.067]	0.456*** [0.065]
year 2008 dummy			0.499***	[0.068]	0.486*** [0.069]
year 2009 dummy			0.540***	[0.070]	0.526*** [0.071]
Number of observations	8809 (807 groups)	8809 (807 groups)	8809 (807 groups)	8809 (807 groups)	
Rho	0.9739	0.9740	0.9750	0.9750	
Within R ²	0.0057	0.0086	0.0525	0.0514	

Notes: All standard errors shown are robust. The year 1999 is omitted from regressions (3) and (4). Two ** indicate significance at the 5% level, *** indicates significance at the 1% level.

With only municipality fixed effects, the ICMS-e policy had a significant positive correlation with protected area. For every 1 point increase in the percentage of ICMS funds passed from states to municipalities, there was a corresponding 5.35% increase in the amount of protected area in a municipality.¹⁶⁷ The dummy variables representing the ICMS-e policy can be used to compare the effectiveness of different types of ICMS-e policy. From regression (2), we can see that policies which reward municipalities for having protected area resulted in a 20.15% increase in protected area over states which had no ICMS-e policies. Contrary to expectations, policies which monitored for quality in protected areas when determining distribution of ICMS-e funds were even more effective, with a 32.57% increase in protected areas over those without any ICMS-e policy.

However, once dummy variables are included, the effect of ICMS-e policies on protected area is much less clear. Only the ICMS-e percentage is significant, but its coefficient is negative, suggesting that states which increase the percentage of funds passed to municipalities for ecological criteria by 1 percentage point will experience a 3.52% *decrease* in the amount of protected area within municipalities, all else equal. All year dummies were significant and positive, showing a clear upward trend in the total area protected from 1999-2009.

¹⁶⁷ The log-transformed dependent variable is useful because it approximates the percentage change in the dependent variable for a given increase in the independent variable. However, this approximation becomes less accurate when coefficients are relatively high. All numbers presented in discussion use the formula $\% \Delta y = 100(e^{\beta} - 1)$ to calculate the exact percentage change in the dependent variable for a 1-unit increase in the independent variable.

Table 3. ICMS-e regressed on log-transformed area protected with municipality and both year and municipality fixed effects

Dependent variable: ln(Area protected)					
Explanatory Variable	ICMS-e alone		With year dummies		
	(1)	(2)	(3)	(4)	
ICMS-e percentage	0.052***	[0.011]	-0.035**	[0.015]	
ICMS-e area only dummy		0.184***		-0.063	[0.058]
ICMS-e quality dummy		0.282***		-0.102	[0.081]
year 2000 dummy			0.033**	[0.014]	0.033** [0.014]
year 2001 dummy			0.084***	[0.024]	0.086*** [0.024]
year 2002 dummy			0.249***	[0.042]	0.233*** [0.041]
year 2003 dummy			0.267***	[0.044]	0.255*** [0.046]
year 2004 dummy			0.316***	[0.052]	0.309*** [0.054]
year 2005 dummy			0.393***	[0.060]	0.382*** [0.061]
year 2006 dummy			0.446***	[0.064]	0.432*** [0.064]
year 2007 dummy			0.476***	[0.067]	0.456*** [0.065]
year 2008 dummy			0.499***	[0.068]	0.486*** [0.069]
year 2009 dummy			0.540***	[0.070]	0.526*** [0.071]
Number of observations	8809 (807 groups)	8809 (807 groups)	8809 (807 groups)	8809 (807 groups)	
Rho	0.9739	0.9740	0.9750	0.9750	
Within R ²	0.0057	0.0086	0.0525	0.0514	

Notes: All standard errors shown are robust. The year 1999 is omitted from regressions (3) and (4). Two ** indicate significance at the 5% level, *** indicates significance at the 1% level.

Before combining multiple other explanatory variables, I tested for the individual significance of each variable with either ICMS-e specification. Table 4 reports all variables which were statistically significant with either the ICMS-e percentage (regressions 1 and 2) or the ICMS-e dummies (regressions 3 and 4), while controlling for both municipality and year fixed effects. Table 5 reports the same information while controlling only for municipality fixed effects. In all regressions not shown in Tables 4 and 5, the explanatory variables other than the ICMS-e were not significant.

Table 4. ICMS-e regressed and other significant explanatory variables regressed on log-transformed area protected with both year and municipality fixed effects

Dependent variable: ln(Area protected)							
Explanatory variable	rural population percent only				ln(rain) only		
	(1)		(2)		(3)	(4)	
ICMS-e percentage	-0.036**	[0.015]			-0.035**	[0.015]	
ICMS-e area only dummy			-0.072	[0.058]			-0.064 [0.058]
ICMS-e quality dummy			-0.981	[0.081]			-0.105 [0.081]
rural population percent	-0.019**	[0.009]	-0.019**	[0.009]			
ln(rain)					7.281*	[4.205]	7.292* [4.209]
year 2000 dummy	0.042**	[0.021]	0.040**	[0.021]	0.033**	[0.014]	0.033** [0.014]
year 2001 dummy	0.087***	[0.031]	0.086***	[0.031]	0.084***	[0.024]	0.087*** [0.024]
year 2002 dummy	0.239***	[0.049]	0.220***	[0.048]	0.250***	[0.042]	0.233*** [0.041]
year 2003 dummy	0.247***	[0.052]	0.235***	[0.054]	0.268***	[0.044]	0.256*** [0.046]
year 2004 dummy	0.288***	[0.061]	0.277***	[0.063]	0.318***	[0.052]	0.310*** [0.054]
year 2005 dummy	0.356***	[0.066]	0.342***	[0.067]	0.395***	[0.060]	0.385*** [0.061]
year 2006 dummy	0.400***	[0.069]	0.382***	[0.070]	0.448***	[0.064]	0.434*** [0.065]
year 2007 dummy	0.421***	[0.074]	0.396***	[0.073]	0.477***	[0.067]	0.458*** [0.065]
year 2008 dummy	0.435***	[0.076]	0.414***	[0.077]	0.500***	[0.068]	0.488*** [0.069]
year 2009 dummy	0.466***	[0.079]	0.445***	[0.080]	0.541***	[0.067]	0.529*** [0.071]
Number of observations	8541 (792 groups)		8541 (792 groups)		8809 (807 groups)		8809 (807 groups)
Rho	0.9754		0.9754		0.9730		0.9730
Within R ²	0.0580		0.0568		0.0536		0.0525

Notes: All standard errors shown are robust. The year 1999 is omitted from all regression. One * indicates significance at the 10% level, ** indicates significance at the 5% level, *** indicates significance at the 1% level. All explanatory variables not shown in this table were not significant when regressed alone with either ICMS-e specification.

When both municipality and year fixed effects were included, the ICMS-e percentage was significant and negative in all cases, while the ICMS-e dummy variables were only significant in one case (with the indigenous population percentage). The coefficients on the ICMS-e variables do not change much when a single other explanatory variable is added – compare the values in regressions (3) and (4) of Table 3 to those in Table 4. What is interesting here is the effect of significant other explanatory variables. In both regressions (1) and (2), the percentage of the population residing in rural households has a negative effect on the amount of area protected, with a 1 percentage point increase in the rural population correlated with about a 1.94% decrease in the amount of protected area within a municipality. This relationship highlights the importance of rural population as a driver of demand for land. While urban populations may increase land demand indirectly through increased demand for agricultural products and other natural resources, it is rural farmers and ranchers who directly impact demand for land.¹⁶⁸ Accordingly, increased demand for land means that, all else equal, land prices are higher, increasing the opportunity cost of establishing protected areas. This is especially true in places where land resources are more limited, which is the case in states with higher population densities.

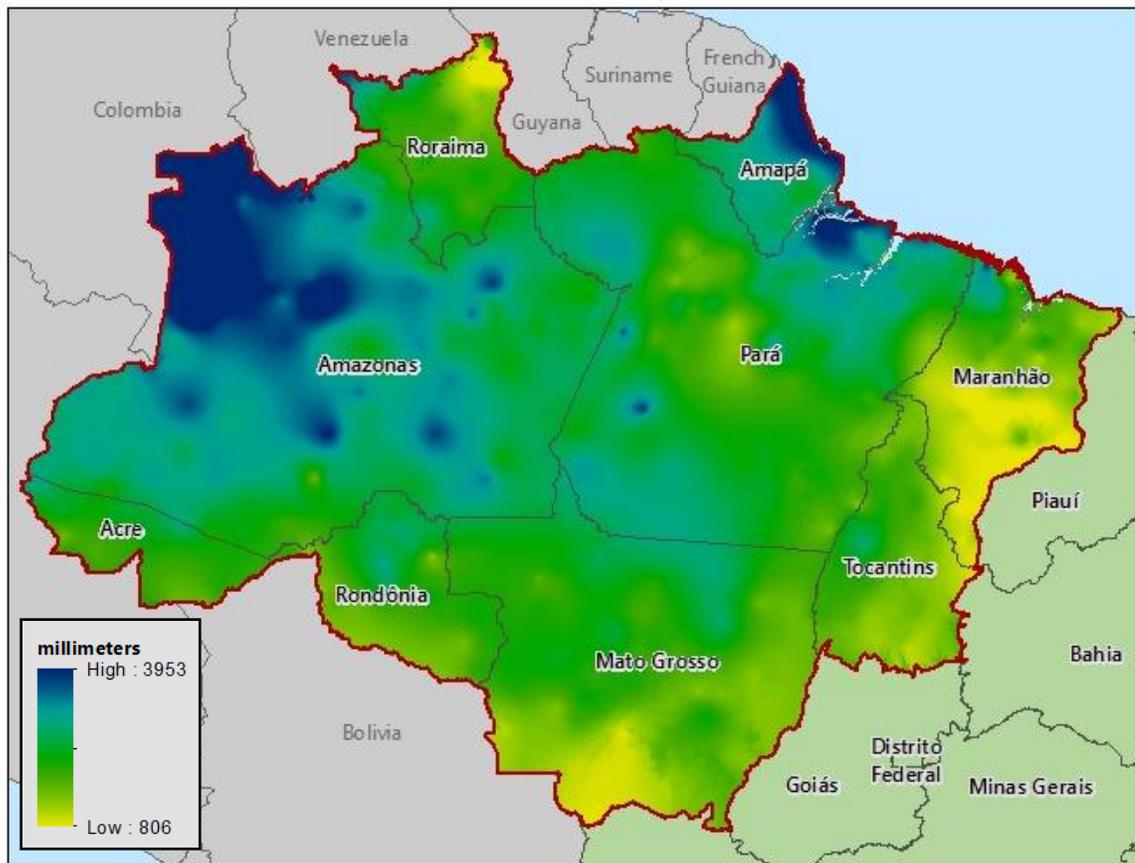
Interestingly, an increase in a municipality's average annual rainfall was correlated with huge increases in protected area; a 1% increase in total rainfall was correlated with an astonishing 145,177.24% increase in the amount of protected area! To scale this

¹⁶⁸ Lykke E. Andersen and Eustáquio J. Reis, *Deforestation, Development, and Government Policy in the Brazilian Amazon: An Econometric Analysis* (Rio de Janeiro, Brazil: Brazilian Applied Economic Research Institute, 1997), 2.

reference, we can use the “mean municipality,” which had an average annual rainfall of 1,881 mm and 15,146 km² of protected area (Table 2).¹⁶⁹ A 1% increase in annual rain to 1,889 mm would increase the protected area to 2.199 *trillion* km², an area larger than not just the Amazon, but almost 300 times the size of the entire country of Brazil. Clearly, this is not a realistic interpretation. An important note is that $\ln(\text{rain})$ was only significant at the 10% level in both regressions (3) and (4), so it has a very wide confidence interval. Taking the lower 95% bound, rain actually has a *negative* effect on protected area. This strongly suggests that, due to random chance and possible spatial correlation, the coefficient on $\ln(\text{rain})$ was vastly overestimated (Figure 5)

¹⁶⁹ These figures do not represent any actually existing municipality, but are rather the means across the whole sample. They can nonetheless serve as a point of reference for estimations such as the one given here.

Figure 5. Average annual rainfall in the Amazon, 1950-2000



Data Source: "Environmental Variables for Modeling the Distribution of Species (AMBDATA)," INPE

However, fine-scale modeling in the Amazon by Chomitz and Thomas found that even when controlling for proximity to roads, cities, and older cleared areas, increased rainfall led to significant declines in the proportion of land cleared for agriculture.¹⁷⁰ These results suggest that although my data may be upwardly biased by omitted variables, rain truly does reduce the demand for land, thereby encouraging the establishment of protected areas.

¹⁷⁰ Kenneth M. Chomitz and Timothy S. Thomas, "Determinants of Land use in Amazônia: A Fine-Scale Spatial Analysis," *American Journal of Agricultural Economics* 85, no. 4 (November, 2003), 1024.

Table 5. ICMS-e percentage and other significant explanatory variables regressed on log-transformed area protected with municipality fixed effects

Dependent variable: ln(Area protected)														
Explanatory variable	ln(population) only		ln(GDP per capita) only		ln(value added) only		Gini coefficient only		ln(cattle) only		Rural population percent only		Indigenous population percent only	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)							
ICMS-e percentage	0.037***	[0.011]	-0.027*	[0.014]	-0.042***	[0.015]	0.055***	[0.011]	0.039***	[0.011]	0.023**	[0.012]	0.040***	[0.010]
ln(population)	0.719***	[0.140]												
ln(GDP per capita)			0.373***	[0.055]										
ln(value added)					0.408***	[0.056]								
Gini coefficient							3.194*	[1.753]						
ln(cattle)									0.226***	[0.061]				
rural population percent											-0.043***	[0.009]		
indigenous population percent													0.043*	[0.025]
Number of observations	8809 (807 groups)	8809 (807 groups)	8809 (807 groups)	8809 (807 groups)	8809 (807 groups)	8809 (807 groups)	8809 (807 groups)	8809 (807 groups)	8541 (792 groups)	8541 (792 groups)	8541 (792 groups)	8541 (792 groups)	7905 (792 groups)	7905 (792 groups)
Rho	0.9727	0.9748	0.9750	0.9735	0.9747	0.9760	0.9757							
Within R ²	0.0196	0.0402	0.0496	0.0071	0.0176	0.0341	0.0060							

Notes: All standard errors shown are robust. One * indicates significance at the 10% level, ** indicates significance at the 5% level and *** indicates significance at the 1% level. All variables not included in this table were not statistically significant alone with the ICMS-e percentage.

Table 6. ICMS-e dummies and other significant explanatory variables regressed on log-transformed area protected with municipality fixed effects

Dependent variable: ln(Area protected)												
Explanatory variable	ln(population) only		ln(GDP per capita) only		ln(value added) only		ln(cattle) only		Rural population percent only		Indigenous population percent only	
	(1)		(2)		(3)		(4)		(5)		(6)	
ICMS-e area only dummy	0.154***	[0.043]	-0.045	[0.054]	-0.085	[0.057]	0.132***	[0.045]	0.110***	[0.043]	0.128***	[0.038]
ICMS-e quality dummy	0.209***	[0.060]	-0.068	[0.073]	-0.146*	[0.082]	0.226***	[0.060]	0.151**	[0.062]	0.223***	[0.052]
ln(population)	0.697***	[0.142]										
ln(GDP per capita)			0.359***	[0.055]								
ln(value added)					0.399***	[0.058]						
ln(cattle)							0.219***	[0.061]				
rural population percent									-0.041***	[0.009]		
indigenous population percent											0.043*	[0.025]
Number of observations	8809 (807 groups)		8809 (807 groups)		8809 (807 groups)		8809 (807 groups)		8541 (792 groups)		7905 (792 groups)	
Rho	0.9729		0.9748		0.9749		0.9748		0.9760		0.9758	
Within R ²	0.0216		0.0394		0.0486		0.0197		0.0353		0.0081	

Notes: All standard errors shown are robust. One * indicates significance at the 10% level, ** indicates significance at the 5% level and *** indicates significance at the 1% level. All explanatory variables not included in this table were not statistically significant alone with the ICMS-e dummies

With only municipal fixed effects included, many more explanatory variables were significant. Table 5 shows the results of regressions with the ICMS-e percentage, while Table 6 shows the results of regressions with the ICMS-e dummies. Any explanatory variables not included in these tables were not significant when regressed with either ICMS-e specification. Both the ICMS-e percentage and both dummies were positive and significant in every case not shown.

In both specifications, population had a significant, positive effect on the amount of area protected (Tables 5 and 6, regression 1). There is no clear reason as to why this is, as many studies have linked increased population with greater demand for land, higher land prices, and therefore increased opportunity cost to the establishment of protected areas.¹⁷¹ It may be that in this case, population is really only acting as a proxy for other variables. As discussed above, rural populations tend to have higher rates of deforestation. A simple linear regression of the rural population percentage on the total population shows a strong negative correlation between the two (P-value = 0.000), so the relationship seen in these regressions may only be a reflection of fact that municipalities with higher populations are more urbanized, and therefore have a lower direct demand for land.

Two explanatory variables, per capita GDP and value added, measure the economic well-being of municipalities and states. GDP per capita is measured at the municipal level and is scaled to population sizes, so it should better show the effects of increased personal wealth. Value added, on the other hand, was collected at the state

¹⁷¹ Arild Angelsen and David Kaimowitz, "Rethinking the Causes of Deforestation: Lessons from Economic Models," *The World Bank Research Observer* 14, no. 1 (February, 1999), 87-89.

level, and is a measure of the total amount of economic activity within the state.

Therefore, value added would be expected to measure the impact of increased economic activity as a whole. Both variables had a significant positive effect on protected area, and value added returned higher coefficients in both the continuous and dummy variable specification of the ICMS-e (Tables 5 and 6, regressions 2 and 3). This suggests that regional economic health is more strongly correlated with increased protected area than individual well-being. What is most striking here is the fact that with these variables included, the effect of the ICMS-e policy is negative and, in the case of the dummy variable specification, not significant. A simple regression of the ICMS-e policy on either GDP per capita or value added shows that the two are highly correlated (P-values of 0.000 in both cases), suggesting that much of the positive effect attributed to the ICMS-e policy when it is regressed without other explanatory variables may simply be a reflection of higher economic activity.

The relationship between wealth and environmental protection is a complicated one which cannot possibly be fully addressed here. In many tropical countries where deforestation is a problem, much of the clearing is done by impoverished workers practicing slash-and-burn agriculture. Without opportunities for off-farm employment, subsistence agriculture may be the only possible option.¹⁷² However, increased economic activity leads to increased demand for consumer goods, so theoretically this could increase land clearing as the demand for natural resources goes up. In the particular case of the Amazon, history has shown that when Brazil's economy grows, land clearing

¹⁷² Ibid., 89

increases, while deforestation slows during times of recession.¹⁷³ These results suggest that the trend may have reversed in recent years, with increased wealth reducing inefficient agricultural practices and consequently the demand for land, allowing leeway for support of conservation measures.

One variable which was significant with only the continuous specification of the ICMS-e is the Gini coefficient, a measure of inequality. An increased Gini coefficient represents greater consolidation of wealth, with a Gini of 1 suggesting that a single person owns all the wealth, while a Gini of 0 represents completely equal distribution of resources. Brazil, which has a long history of inequality, typically has quite high Ginis relative to other South American countries.¹⁷⁴ In this study, the Gini coefficient, which was collected at the state level, had a positive effect on the amount of protected area (Table 5, regression 4). This suggests that increased inequality increases protected area, a problematic conclusion in an area where social and environmental values often conflict. Though the coefficient in the table is high, it's worth noting that Gini coefficients can only range from 0 to 1, so an interpretation of the coefficient should model increases of no more than a few tenths to obtain a realistic interpretation. With this in mind, an increased Gini has roughly approximate effects as increased GDP per capita or state value added. The fact that the Gini is much less significant (not even at the 10% level in the dummy variable specification) highlights the fact that Ginis measure a nebulous

¹⁷³ Philip M. Fearnside, "Deforestation in the Brazilian Amazonia: History, Rates, and Consequences," *Conservation Biology* 19, no. 3 (June, 2005), 681-682.

¹⁷⁴ Lee J. Alston, Gary D. Libecap, and Bernardo Mueller, "Land Reform Policies, the Sources of Violent Conflict, and Implications for Deforestation in the Brazilian Amazon," *Journal of Environmental Economics and Management* 39 (2000), 165.

concept; inequality in wealth distribution has many implications, and its effects are not so clear as simple economic growth. Another indication of the Gini's status as a poor predictor of protected area is its low R^2 – the ICMS-e percentage and Gini coefficient together only explain a mere 0.71% of the variation in protected area, compared to approximately 4% for GDP per capita and 5% for value added.

Surprisingly, the number of cattle within a municipality had a strong positive correlation with protected area, despite the fact that cattle ranching is one of the main land uses driving up demand within the Amazon (Table 5, regression 5; Table 6, regression 4). Given the historical trends underlying Amazonian deforestation, it is difficult to construct an explanation for why increased ranching might have a directly positive effect on protected area. The problem here may lie with the fact that the number of cattle is really only a proxy for the type of ranching which is most detrimental to conservation. Problematic ranching in the Amazon is characterized by extensive production, overgrazing, and often land cleared for speculative purpose or to protect against expropriation by squatters.¹⁷⁵ High numbers of cattle, then, could be indicative of either many large ranches, or ranches which practice efficient land use and have concentrated numbers of cattle. Ideally, this regression would include total pasture land to more accurately model extensive ranching, but this information was not available at the municipal level.

Both demographic variables for rural population percentage (Table 5, regression 6; Table 6, regression 5) and indigenous population percentage (Table 5, regression 7;

¹⁷⁵ Fearnside, *Deforestation in the Brazilian Amazonia: History, Rates, and Consequences*, 681

Table 6, regression 6) were significant. Rural population percentage had a strong negative effect on protected area; the probable reasons for this have already been discussed above. Indigenous population was not highly significant and had a low R^2 , but nonetheless was positively correlated with increased protected area. This is unsurprising, as one of the categories of protected area is indigenous lands, making the presence of large indigenous populations clearly relevant.

For all of the following regressions I adopted a set of conventions. Because the ICMS-e percentage in every regression done previously had a higher significance than the dummy variable specification of ICMS-e, I used the percentage formulation exclusively. Year dummies, if included, are not shown in the tables individually, but only jointly. In every case, they were all positive and jointly significant at the 1% level.

For the next set of regressions, I looked more closely at some of the patterns suggested by the above analysis. First, I examined whether controlling for rural population percentage and population simultaneously would decrease the significance of the population variable, which had an unexpectedly large positive effect on protected area. I also attempted to moderate the effect of rain in the regression controlling for both municipality and year fixed effects by adding proxy variables for the isolation of the municipality, which I believed to be causing omitted variable bias in regressions (3) and (4) of Table 4. Specifically, I included the rural population percentage, which tends to increase in more remote areas, and the total population, which is much lower in areas in the far west of the Amazon, where rainfall is highest. These results are shown in Table 7.

Table 7. Controlling for omitted variable bias: ICMS-e percentage and other explanatory variables regressed on log-transformed area protected

Dependent variable: ln(Area protected)				
Explanatory variable	(1)		(2)	
ICMS-e percentage	0.015	[0.012]	-0.035**	[0.015]
ln(population)	0.596***	[0.152]	0.226	[0.146]
rural population percentage	-0.038***	[0.009]	-0.020**	[0.009]
ln(rain)			7.854*	[4.612]
year dummy variables			included	
Number of observations	7905 (792 groups)		7905 (792 groups)	
Rho	0.9748		0.9730	
Within R ²	0.0420		0.0602	

Notes: All standard errors shown are robust. The year 1999 is omitted from regression (2), and all year dummies were jointly significant at the 1% level. One * indicates significance at the 10% level, ** indicates significance at the 5% level, *** indicates significance at the 1% level.

Regression (1) shows that even when rural population is controlled for, the total municipal population is still significant at the 1% level. As suspected, the coefficient on population is reduced with the inclusion of the rural population percentage, but it still has a large positive effect on protected area. This rejects my previous hypothesis that population was only positively significant because it is correlated with increased urbanization, which tends to decrease the direct demand for land. Instead, it appears that either population truly does have a positive impact on the amount of protected area, or there are still other omitted variables which are correlated with population, artificially increasing its coefficient. Notably, the ICMS-e policy is not significant in regression (1), suggesting that it has only a minor influence on protected areas compared to demographic variables.

Attempting to control for omitted variables correlated with the average annual rainfall was not successful; rain still has an implausibly large coefficient, though it is much less significant, widening its confidence interval even further (regression 2). This

regression supports the conclusion that rain is a direct deterrent to agricultural production, decreasing the demand for land and therefore the opportunity cost of establishing protected areas.¹⁷⁶ However, the proxy variables I included were not particularly accurate proxies. A better choice would be to use some measure of spatial distance either N-S or E-W, which would directly control for spatial effects. Alternatively, Chomitz and Thomas controlled for isolation from human settlements by including variables indicating whether an area was within a buffer zone around major cities and roads.¹⁷⁷ Inclusion of something along these lines would help to determine if rain itself was deterring alternative land uses, if there was spatial correlation in the data, or if it is only distance from major settlements which decreases the demand for land.

For the final set of regressions, I first ran a model of all the variables which I expected to be the most important determinants of protected area from the review of existing literature, both with and without year fixed effects. The first variable included was value added, as historical patterns of land use in the Amazon show that macroeconomic variables have a strong role to play.¹⁷⁸ In addition, value added was highly significant when regressed with either ICMS-e specification, suggesting it has a large impact on my dataset.

The next two variables included were the area of temporary agriculture and number of cattle. Both of these variables were lagged by one period and compared to the results using the non-lagged coefficient (Table 8, regressions 1-3). The model with

¹⁷⁶ Chomitz and Thomas, *Determinants of Land use in Amazônia: A Fine-Scale Spatial Analysis*, 1016-1028

¹⁷⁷ *Ibid.*, 1024

¹⁷⁸ Fearnside, *Deforestation in the Brazilian Amazonia: History, Rates, and Consequences*, 681-682

the higher within R^2 is taken to be the one with the strongest explanatory power and was combined with the remaining explanatory variables. There were several reasons why it might make sense to include these lagged variables. First, it is important to keep in mind that the temporary agriculture variable primarily represents soybean farms. Literature suggests that while soybean farming does not have an immediate direct effect on land use, the roads which are built to new farms under pressure from the soybean lobby bring settlers, loggers, and others who increase the demand for land.¹⁷⁹ Therefore, the biggest effect of temporary agriculture in determining the demand for land will not necessarily be felt immediately. Although there is not quite as clear a reason to use the lagged value for cattle as with temporary agriculture, this formulation is consistent with Andersen and Reis' findings regarding the determinants of demand for land in the rural Amazon.¹⁸⁰

The last two variables included in this regression were demographic: the rural population percentage and the indigenous population percentage. Both these variables had significant effects when regressed on protected area with only the ICMS-e percentage (Table 4, regressions 1 and 2; Table 5, regressions 6 and 7; Table 6, regressions 5 and 6). Empirical studies suggest that the rural population is a key determinant of land use in the Amazon,¹⁸¹ and if the rural population percentage is viewed as a proxy for such variables as the activity of rural workers' groups, then it would

¹⁷⁹ Ibid., 682

¹⁸⁰ Using lagged values for the effect of cattle herds on the demand for land is also consistent with Andersen and Reis, *Deforestation, Development, and Government Policy in the Brazilian Amazon: An Econometric Analysis*, 13

¹⁸¹ Ibid., 13

likely have an enormous effect on the demand for land uses other than protected area.¹⁸²

The indigenous population percentage was also included because of the obvious effect it might be expected to have on increasing the amount of indigenous land within a municipality, and because the debate over the role of indigenous people in preventing deforestation makes it an interesting variable to consider.¹⁸³

These regressions were performed both with and without year fixed effects. Finally, I ran a regression with year fixed effect *not* including value added. I did this because, when value added was regressed with the ICMS-e percentage alone, it caused the coefficient on the ICMS-e percentage to be negative. I wanted to test whether removing the effects of value added caused the ICMS-e percentage to be positive when multiple other explanatory variables were included. The results are shown in Table 8.

¹⁸² Alston, Libecap, and Mueller, *Land Reform Policies, the Sources of Violent Conflict, and Implications for Deforestation in the Brazilian Amazon*, 180

¹⁸³ D. Nepstad et al., "Inhibition of Amazon Deforestation and Fire by Parks and Indigenous Lands," *Conservation Biology* 20, no. 1 (2006), 69-70.; Carlos A. Peres, "Indigenous Reserves and Nature Conservation in Amazonian Forests," *Conservation Biology* 8, no. 2 (June, 1994), 586.

Table 8. ICMS-e percentage and other explanatory variables suggested to be significant from literature review regressed on log-transformed area protected

Dependent variable: ln(Area protected)										
Explanatory variable	no lagged variables		temporary agriculture lagged		cattle lagged		with year dummies		without value added	
	(1)		(2)		(3)		(4)		(5)	
ICMS-e percentage	-0.041***	[0.014]	-0.042***	[0.014]	-0.042***	[0.014]	-0.033**	[0.013]	-0.041***	[0.014]
ln(value added)	0.314***	[0.059]	0.313***	[0.058]	0.319***	[0.061]	-0.291	[0.211]		
ln(temporary agriculture)	0.007	[0.027]			0.008	[0.027]				
ln(temporary agriculture) _{t-1}			0.017	[0.027]			0.014	[0.028]	0.015	[0.028]
ln(cattle)	0.053	[0.053]	0.052	[0.053]			0.043	[0.053]	0.041	[0.053]
ln(cattle) _{t-1}					0.031	[0.048]				
rural population percent	-0.018**	[0.009]	-0.018**	[0.009]	-0.019**	[0.009]	-0.018*	[0.009]	-0.018*	[0.009]
indigenous population percent	0.023	[0.024]	0.023	[0.024]	0.023	[0.024]	0.020	[0.024]	0.021	[0.024]
year dummy variables							included		included	
Number of observations	7905 (792 groups)		7905 (792 groups)		7905 (792 groups)		7905 (792 groups)		7905 (792 groups)	
Rho	0.9775		0.9775		0.9775		0.9777		0.9776	
Within R ²	0.0502		0.0504		0.0499		0.0539		0.0536	

Notes: All standard errors shown are robust. The year 2000 is omitted from regressions (4) and (5), and all year dummies were jointly significant at the 1% level. One * indicates significance at the 10% level, ** indicates significance at the 5% level and *** indicates significance at the 1% level.

Lagging temporary agriculture improved the model fit, while lagging the number of cattle did not (Table 8, regressions 1-3). This aligns with the suggestion that lagged temporary agriculture represents the indirect effects of soybean farming. Only value added and the rural population percent were significant, and each had the same signs in this regression as it did in previous ones. Including dummies to control for year fixed effects reduces the significance of the rural population and makes the value added not significant (regression 4). Removing it from the equation, however, does not change the signs or the significance of any of the variables (regression 5).

In every single regression, the ICMS-e has a significant negative effect on the area protected, with a 1 percentage point increase in the ICMS-e correlated with a decrease in the amount of protected area by 3.33-4.23%. Because these models have some of the best goodness of fit of all tested models, and because the included variables are those which were suggested to be positive in the literature review, the conclusion of this analysis, is that, when year and municipality fixed-effects are controlled for, ICMS-e policies actually have a *negative* effect on the establishment of new protected areas. This is a surprising conclusion, and it is not clear what could be driving this. Some of the problem might lie in the fact that the sample size was relatively small, with not a large amount of variation in the ICMS-policies at the municipal level, as they were determined only at the state level. Perhaps inclusion of the rest of the states of Brazil would yield significant results.

It is also interesting to note that when either year fixed-effects or some measure of economic well-being are not included, the ICMS-e policies tend to have positive

coefficients. This suggests that perhaps the reason that the ICMS-e appears negative in so many of these regressions is that it is strongly correlated with these variables. In fact, this is clearly true – more states had ICMS-e policies over time, and there was a strong positive relationship between ICMS-e and both value added and GDP. Again, inclusion of a greater sample size might help to disentangle the effects of these variables, giving a more accurate picture of how the ICMS-e truly affected the establishment of new protected areas.

A few important things to note in *all* of the above regressions are the high rho values and the relatively low R^2 . The high rhos (above 0.96 for every regression) suggest that the panel dataset explains a huge percentage of the variation in the error term, as the variation across municipalities was a major determinant of protected area. This means that there is little variation remaining to be attributed to the included explanatory variables, a fact which is reflected in the low R^2 . High rho values are not inherently problematic; in fact, this strongly supports the use of the fixed-effects model, as municipality fixed effects had an enormous influence. However, it does mean that if there are sampling errors or other problems in the data, these effects may be magnified, as their influence will be relatively large in comparison to the variation not explained by municipality-level fixed effects. There is not a clear way to stop this from occurring, except to minimize the errors in the data by controlling for omitted variables and including proxies or instrumental variables as needed.

It is worth noting that some of the assumption made regarding the data may have been incorrect, leading to biases in the calculated effects. For instance, I did not

have year-level data on rural or indigenous population percentages, so I assumed a linear transformation between the years 2000 and 2010. While this could have been true, there is no way to know if there were large fluctuations in the rural or indigenous population during this time period which are not reflected in the data. In addition, the quality of some of the GIS data is not perfect; indigenous lands and protected areas do not always have well-defined borders. Issues with the dependent variable's reliability could significantly bias the results of the entire study. Ground-truthing of calculated values would be an invaluable tool to prevent this from occurring.

CHAPTER V. CONCLUSIONS AND POLICY RECOMMENDATIONS

This study suggests that, by themselves, ICMS-e policies have a positive impact on the establishment of protected areas. However, when other variables are controlled for, the significance of the ICMS-e policy declines, and, particularly when either wealth measurements or fixed effects of both municipalities and years are included, the ICMS-e policy actually has a *negative* impact on the establishment of protected areas. The reasons for this relationship are not clear. It could be caused by the fact that the sample size was too small and had limited variation; with only the states of the Legal Amazon to consider, there were not significant enough differences to truly capture the impact of the ICMS-e. Further studies should investigate a broader area, including not just the Legal Amazon, but also the other states of Brazil. Perhaps with this larger sample size and greater variation, the true effects of the ICMS-e could be teased out of the data.

A perhaps more likely explanation is that even if the ICMS-e has any positive impact on the creation of new protected areas, it is a minimal one compared to the effects of problematic policies which have plagued the Amazon for the last sixty years. The continued significant negative effect of increased rural population on protected area throughout all the simulations points to the fact that the presence of large numbers of impoverished and generally landless farmers will overshadow any positive outcomes from policies intended to increase protected areas and decrease deforestation. Poor land tenure policies, a problematic distribution of land, and high agricultural pressures will continue to be the main drivers Amazonian deforestation unless serious changes occur.

Therefore, the true conclusion of this study is not a strong statement about the ICMS-e, but rather a cautionary tale regarding alternative forces which have led to the massive increases in deforestation seen in the past twenty years. Policies involving squatters should be standardized across the area to increase land tenure and prevent unnecessary clearing.¹⁸⁴ In addition, powerful agricultural interests should not be subsidized and supported with government-built infrastructure. While there is a need to balance economic devilmment in this impoverished region, assisting large cattle and soybean farmers does not accomplish this goal and has significant environmental impacts.¹⁸⁵ Sustainable use protected areas are a better alternative, and one that actually has relatively strong support at the local level in Brazil.

Other significant variables in increasing the amount of protected area included increased average annual rainfall. This effect may be a legitimate one, with increased rainfall leading to lower demand for land for agricultural purposes and therefore a lower opportunity cost of establishing protected areas.¹⁸⁶ However, it could also be that increased rainfall is related to a spatial autocorrelation, which was not controlled for in this study. Alternatively, the effect of rainfall may be correlated with increased distance

¹⁸⁴ Lee J. Alston, Gary D. Libecap, and Bernardo Mueller, "Land Reform Policies, the Sources of Violent Conflict, and Implications for Deforestation in the Brazilian Amazon," *Journal of Environmental Economics and Management* 39 (2000), 162. Bruce Albert, "Indian Lands, Environmental Policy and Military Geopolitics in the Development of the Brazilian Amazon: The Case of the Yanomami," *Development and Change* 23 (1992), 35. Emilio F. Moran, "Deforestation and Land use in the Brazilian Amazon," *Human Ecology* 21, no. 1 (1993), 1.

¹⁸⁵ Lykke E. Andersen and Eustáquio J. Reis, *Deforestation, Development, and Government Policy in the Brazilian Amazon: An Econometric Analysis* (Rio de Janeiro, Brazil: Brazilian Applied Economic Research Institute, 1997), 21-22.

¹⁸⁶ Kenneth M. Chomitz and Timothy S. Thomas, "Determinants of Land use in Amazônia: A Fine-Scale Spatial Analysis," *American Journal of Agricultural Economics* 85, no. 4 (November, 2003), 1027.

to human settlements, thereby biasing the coefficient on the rainfall variable upward.

Controlling for either of these factors would help to demonstrate whether the effect of rainfall truly exists.

As international pressure on the Brazilian government continues, the fate of the Amazon as a protector of biodiversity and a strong tool for carbon sequestration hangs in the balance. Protected areas are an important part of this equation, but without improved monitoring and maintenance, they will not serve much purpose. Though it was not represented in my regressions, the ICMS-e policies which are likely to have the most substantial impact are those which provide administrative support for maintaining protected areas and which increase the institutional capacity of municipalities. Anecdotal reports from states which have implemented ICMS-e laws for more than 10 years show that one of the main positive impacts of the ICMS-e is a greater support and concern for protected areas by municipalities. Increased local acceptance of protected areas is a key goal in long-term conservation.¹⁸⁷ In this case, even if the ICMS-e has no direct impact on the size of protected areas, it can still play an important role.

¹⁸⁷ Britaldo Silveira Soares-Filho et al., "Modelling Conservation in the Amazon Basin," *Nature* 440 (March, 2006), 522.

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