Policy Interventions in the Amazon Rainforest

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In 2010, the Food and Agricultural Organization of the United Nations (FAO) documented a decrease in the world deforestation over the previous ten years. The recent slowdown is good news, but the rate still is alarmingly high.

To gain some perspective, the world has approximately 4 billion hectares of forested area – about 31% of total land area. During the 1990s the world lost 16 million hectares of forests per year, while during the 2000s we lost around 13 million hectares per year. Because some areas experience significant afforestation and forest regrowth, the *net* forest loss worldwide went down from 8.3 million hectares per year in the 1990s to 5.2 million hectares annually between 2000 and 2010. The reduction on the deforestation rate is considerable, but the rate is still high. Five million hectares is approximately the area of Costa Rica. Losing every year a forested area of the size of Costa Rica seems far from desirable.

The recent slowdown explains the reduced carbon emissions from deforestation. According to the 2013 report of the Intergovernmental Panel on Climate Change (IPCC), deforestation and forest degradation were responsible for approximately 20 percent of the average global anthropogenic greenhouse gas emissions per year in the 1990s. In the last decade, it was responsible for 10 percent. Once more, although this is good news, the share is still significant. Forests are considered particularly important in climate change mitigation because of its role as storage of carbon. In 2010, FAO estimated that the world's forests store almost 290 billion tons of carbon in their biomass alone. When forests are converted to another land use, carbon is released into the atmosphere contributing to global greenhouse effects.[1]

Forests also are important for other reasons. They provide a variety of essential products and environmental services. Forest products include timber, fiber, rubber, and

[1] The total anthropogenic carbon emissions per year in the 1990s was approximately 8 billion tons of carbon; and was approximately 9.2 billion tons of carbon in the 2000s (IPCC, 2007, 2013).

medicines, among others. The environmental services include reserve of biodiversity, soil and water conservation, and regulation of both local and global climate.

The combination of high levels of deforestation and the importance of the environmental services made the general public claim for solutions – and organize campaigns of the type “let’s save the rainforest.” As forests become relatively scarcer, their social value increase. The problem here is that the economic system by itself cannot provide the optimal amount of forests’ environmental services. When deforesting, the local agents do not take into account the losses (the external costs) they impose on others, such as emissions of carbon. As a result, deforesters clear more land than they would if they had to pay for the external costs. Forest services are therefore underprovided – and are a well-known case of the so-called externalities.

The market failure suggests room for policy interventions. However, to be effective, the interventions have to be carefully designed. Ideally, the policy should impose on deforesters the external costs they impose on others. The additional cost of deforesting a plot of land should equal the additional benefit of preserving the land. If the policy imposes too much additional costs on deforesters, it may exceed the additional benefits; if, on the contrary, the policy does not impose high enough costs, deforestation will continue excessive. The first main practical difficulty here is that measuring the social benefits of forests is far from trivial.

Another possibility is to set a goal – say, reduce deforestation to some specific level, not necessarily optimal – and achieve the result with the smallest possible costs. In this case, instead of an *optimal* policy, one would have a *cost-effective* policy. Eliminating wasteful expenditures are an important objective by itself and help avoid political backlashes. Yet, measuring the costs of policies are also not trivial – although not as challenging as putting a money value on forests benefits. Some costs are explicit, such as monitoring costs, for example, but others are implicit, such as farmers’ opportunity costs of land use. The difficulty of measuring both benefits and costs of forests may induce policy makers to pursue some target regardless of the costs. That is however counterproductive: poorly designed policies may have perverse effects contrary to what was originally intended. To be successful, policy interventions must consider its potential costs and benefits, and, of course, must be adjusted to the specificities and contexts of the problem at hand.

Most of the recent net world's forest loss – mainly the conversion of tropical forests to agricultural land – occurred in South America (about 4 million hectares per year) followed by Africa (about 3.4 million hectares per year). Oceania also registered losses, while forested area remained stable in North and Central America and expanded in Europe and Asia (FAO, 2010). Not surprisingly, the deforestation in Brazil, particularly in the Amazon rainforest, has received considerable attention both in the media and in the technical literature. Brazil has 35% of the worldwide primary forests. Primary forests consist of native species with no clearly visible indications of human activities and are such that the ecological processes have not been significantly disturbed. They account for one third of the existing forests. The high levels of deforestation rate in the planet's largest rainforest tract has made Brazil's contributions to global deforestation disproportionally large. Brazil is the sixth major emitter of greenhouse gases in the world (IPCC, 2007) and, according to the 2009 Brazilian inventory of greenhouse gases emissions, 76% of the Brazilian emissions come from land-use change, mainly deforestation.

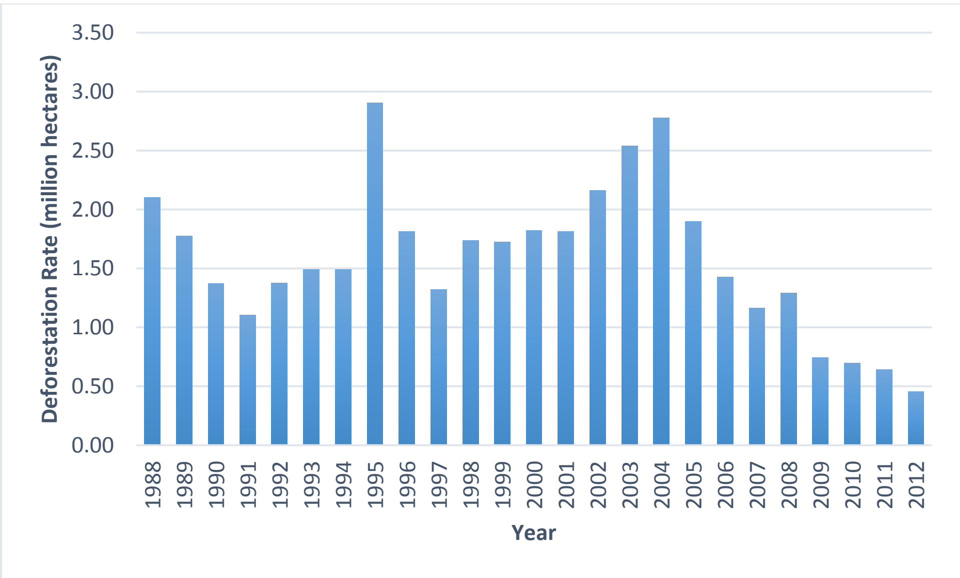
Below I discuss some of the policies implemented in the Brazilian Amazon with a focus on their potential costs and benefits. I also discuss some potential impacts of policies that have been considered in the technical literature but not yet adopted.[2]

[2] An example of a poorly designed policy is the case of the big leaf mahogany tree in the Brazilian Amazon. Concerns about its extinction in the 1990s made the Brazilian government introduce a series of regulations that culminated into the prohibition of extraction and trade of mahogany in October 2001. However, the identification of mahogany by physical inspection, normally done at the port, is difficult and requires an expert. Exporters therefore have opportunities to smuggle mahogany as a different species. Selected timber species have trade codes that exporters have to specify. But exporters can take advantage of the residual classification trade code "other tropical timber species." Chimeli and Boyd (2010) showed strong evidence that the mahogany timber was being smuggled and exported under the residual classification. The specie still is listed as endangered in the appendix II of the United Nations Convention of International Trade of Endangered Species of Wild Fauna and Flora (since November 2002). Some experts believe the problem is worse now than before the prohibition, because lack of extraction property rights may have resulted in overexploitation.

I. DEFORESTATION IN THE AMAZON

Similar to the international pattern, the deforestation in the Amazon slowed down recently (figure 1). After achieving a peak in 2004, when 2.7 million hectares were deforested, the rate reduced to almost half million hectare in 2012. The total accumulated deforestation until 2012 was approximately 40 million hectares – corresponding to almost 20% of the Brazilian Amazon total area.

Figure 1. Deforestation Rate in the Brazilian Legal Amazon.



Source: INPE/PRODES

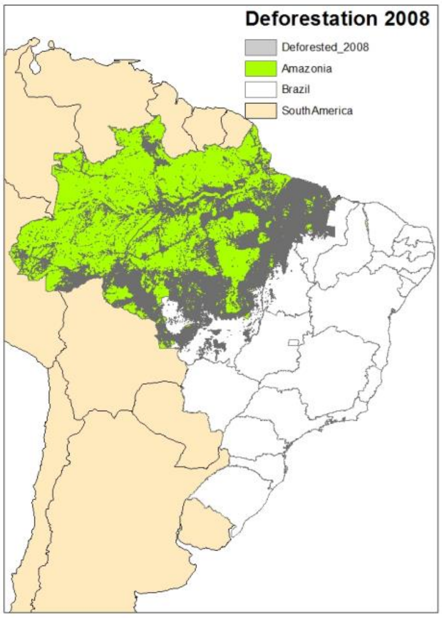
Part of the recent slowdown may be explained by the increased monitoring efforts that took place after 2004. But it also may be explained by variations in agricultural prices, particularly the prices of beef, soybeans and corn, which are the most important products in the Amazon.

In 2010, the majority of the deforested area in the Brazilian Amazon was used for pasture: about 62%, according to classification based on satellite imagery (INPE/TerraClass, 2013). Most of the cattle is used to produce beef. Brazil has the largest number of cattle in the world, 185 million in 2010, of which approximately 43%

were in the Amazon. Brazil also is the second largest producer of beef and the largest beef exporter in the world.[3]

Cropland occupied approximately 5.4% of Amazon's deforested area in 2010. Soybeans is the most important crop in the Legal Amazon (53% of the cropland in 2010), followed by corn (21%). The country became the largest exporter of soybeans in the world in 2012, surpassing USA.[4] Although cropland do not occupy an area as large as pastures, it is located in an important frontier area. Most of the deforested area is concentrated in the southern and eastern parts of the Amazon, which is known as the "Arc of Deforestation". Production of soybeans and corn are located mostly in the South Amazon and are directed to international markets. Figure 2 and 3 present the spatial distribution of land use in 2008.

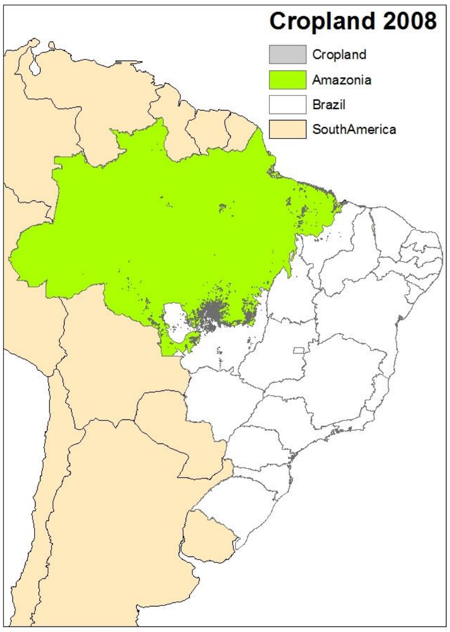
Figure 2. Spatial Distribution of Deforestation, 2008.

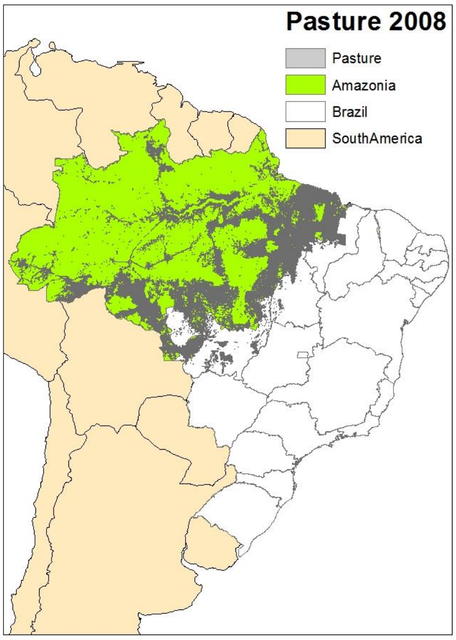


Source: INPE/PRODES and INPE/TerraClass 2008.

[3] Sources: USDA, www.fas.usda.gov/psdonline/, and IBGE, Pesquisa Pecuaria Municipal.
[4] Sources: USDA, www.fas.usda.gov/psdonline/, and IBGE, Produção Agricola Municipal.

Figure 3. Spatial Distribution of Cropland and Pasture, 2008.

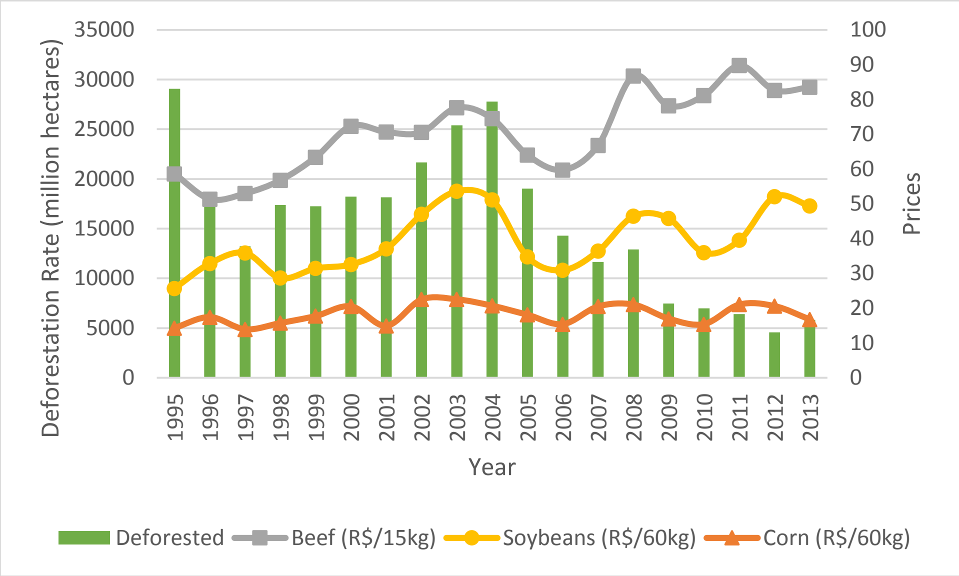




Source: INPE/PRODES and INPE/TerraClass 2008.

Figure 4 presents the evolution of the international prices of soybeans, corn and beef, together with the deforestation levels. The figure suggests that, indeed, there seems to be a positive correlation between deforestation and prices. The slowdown of deforestation after 2004 may be partly explained by the decrease in prices. Yet, a point noteworthy mentioning is that the increase in prices observed after 2006 were not followed by higher levels of deforestation. The claim that the government strategy has been successful in preserving the rainforest has been largely based on this fact.

Figure 4. Deforestation Rate, Price of Beef and Price of Soybeans. [5]



Source: INPE/PRODES, SEAB-PR. Prices deflated to 2010 Brazilian Reais.

But what were the strategies that the government adopted? How much do the strategies explain the recent slowdown on deforestation? What about their associated costs and benefits?

II. POLICY INTERVENTIONS

In Brazil, if a farmer wants to clear a fraction of her land, she needs to hold many licenses and authorizations, including a detailed plan of management that must be approved by the Brazilian Protection Agency (IBAMA). The requirements are costly, time consuming and may take several months to be approved (Hirakuri, 2003). In addition, landowners are obligated to keep 80% of their land in native forest. Sanctions for forest-related violations include fines ranging from US$ 2,300 to US$ 23,000 per hectare, the seizure of products and equipment, and the suspension of activities. The

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[5] Agricultural prices collected at the Agriculture and Supply Secretariat of the State of Parana. Prices were deflated to year 2010 Brazilian reais (R$) using the official inflation price index IPCA.

fines are extremely costly to farmers in view of their average gross revenue per hectare, which was US$ 120/ha according to the Agricultural Census of 2006.

However, the legislation was not fully enforced in the past. The proportion of deforested area (according to the satellite images) that received fines was impressively small before 2005: approximately 0.15% in 2003; 0.1% in 2004; and 1.2% in 2005. The pattern started to change in 2006. The share increased to 7.9% in 2006, and exploded afterwards: 49% in 2007; 44% in 2008; 51% in 2009; and 24% in 2010.[6]

The turning point was the launch of the Action Plan for the Prevention and Control of Deforestation in the Legal Amazon (PPCDAm) in 2004. The program was possibly a response to the increasing levels of deforestation in the late 1990s and early 2000s. It involved integrated actions across different government agencies and focused on two main areas: (a) improvements on both the remote sensing-based monitoring and on the quality (and number) of the protection agency supervisors; and (b) the expansion of protected areas.[7]

The improvement on the remote sensing-based monitoring was probably the most important change at that time. The National Institute for Space Research (INPE) developed a satellite-based system (called DETER) that identifies deforested areas in almost real time – the satellite images are captured and processed in every 15 days. Combined with the improvements in the quality and number of the Brazilian Protection Agency (IBAMA) personnel, the costs of identifying and acting upon areas with illegal deforestation were considerably reduced. Before the implementation of the system, IBAMA inefficiently relied on voluntary reports to monitor the Amazon. It is not hard to imagine the difficulties in monitoring an area of approximately 400 million hectares with no help from real-time satellite imagery.

The expansion of protected areas were also significant: between 2002 and 2010, the government created more than 60 million hectares of conservation units and indigenous land, totaling 237 million hectares in 2010 (about 46% of the Legal Amazon).

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[6] Based on information provided by IBAMA in a personal message.
[7] The program also focused on improving land tenure and on promoting sustainable practices.

In addition to these efforts, in 2008 official federal credit agencies were forbidden to provide loans to agricultural establishments that were not in compliance with the environmental legislation. Furthermore, in the same year, the government issued a list of 36 municipalities with high deforestation rates classified as in need of priority actions. The listed municipalities became subject to stricter policy actions and more rigorous monitoring. The list has been issued every year since and its criteria are based on the municipalities' (i) total area deforested, (ii) total area deforested in the previous three years, and (iii) increases in deforestation rate in at least three of the previous five years.[8]

Assunção and co-authors have been investigating by how much the slowdown on deforestation can be credited to the policy interventions (Assunção et al., 2012, 2013a, 2013b). They have found significant impacts. For example, their estimates suggest that the policies may have avoided the deforestation of 6 million hectares between 2005 and 2009, corresponding to half of the counterfactual deforestation that would have occurred if the policies had not been adopted (Assunção et al., 2012).

During the same period, 2005 to 2009, IBAMA applied 24,161 fines totaling about US$ 7.34 million. The farmers however were largely able to avoid paying the fines: the revenues collected were only 0.6 percent of the total value (TCU, 2009). In spite of this fact, it is conceivable that the expected costs of illegal deforestation, including the non-pecuniary costs, increased considerably. Assunção et al. (2013b) estimate that the deforestation observed between 2007 and 2011 were 75% smaller than it would have been in the absence of the fines.

The strategies adopted by the Brazilian government are known as "command-and-control" policies. Command-and-control policies establish quantitative targets that must be complied with – regardless of the economic costs and benefits. To my knowledge, few attempts have been made to evaluate the costs and benefits of the Brazilian policies.

II.a. The Costs of Policy Interventions

Assunção et al. (2013b) provide a simple back-of-the-envelope cost-benefits analysis. They compare the monitoring costs of the policies (measured as the sum of IBAMA

[8] The Presidential Decree 6.321/2007 established the legal basis for these actions.

and INPE annual budgets) with the monetary benefits of the avoided carbon emissions. Assuming that deforesting one hectare would release 100 tons of carbon into the atmosphere, they conclude that any price of carbon set above US$ 0.76/tCO_2 would make the benefits of preservation compensate the costs. Greenstone et al. (2011) calculates the worldwide social cost of carbon for 2010 to be around US$ 21/tCO_2 – the social cost is based on dynamic macroeconomic models of climate change. The calculations suggest significant gains from the policies adopted by the Brazilian government.[9]

Although very informative, the calculations do not consider all possible costs. For example, they do not include the opportunity cost of farmers. In a different research line, I estimated farmers' opportunity costs of land use under different policy interventions (Souza-Rodrigues, 2014). I focused on three possible policies: (a) payments to avoid deforestation, (b) taxes on agricultural land, and (c) the existing rule that imposes a 20% limit on deforested area allowed on private properties.

Widespread payments programs and taxes on agricultural land have not yet been implemented in the Amazon. And the 20% limit has not yet been fully enforced: farmers' deforested 60% of their properties according to the Agricultural Census of 2006, and the fines issued after 2006 were mostly directed to new deforested areas. For these reasons, I adopted an indirect approach. I exploited variation in transportation costs to infer the value of agricultural land relative to forested land. Intuitively, as transportation costs increase, the value of the agricultural land may decrease more than the value of forested land, causing less deforestation in farms located away from the port than in the farms that are close to the port. Because payments and taxes intend to reduce the relative value of agricultural land, I can use information on transportation costs to infer how farmers would respond to these policies and, so, calculate their private opportunity costs of land use.[10]

[9] IBAMA's budget for 2011 was US$ 560 million, and INPE's budget for 2010 was US$ 125 million. Only a share of the budgets are allocated to monitoring deforestation and enforcing the law.

[10] There exits taxes on rural properties in Brazil. However, they are not of the type I consider. The rates increase with the total area of the property and decrease with the degree of utilization (up to the 20% limit). So, the rates provide incentives to use as much agricultural land as the law permits. Furthermore, the rates are levied on the private value of the property. They therefore do not reflect the external costs of land use.

According to my calculations, the 20% limit required by law, would have cost farmers US$ 4.7 billion per year if perfectly enforced. Given this magnitude, it is not surprising that farmers have systematically tried to alter the legislation since its implementation – they would be willing to pay US$ 4.7 billion per year to avoid the enforcement of this rule. A tax of US$ 40 per hectare of agricultural land could also result in 80% of forest cover, but it would have been roughly ten times less expensive: farmers would have lost approximately US$ 484 million per year – provided the tax revenues were redistributed to them. Payments of US$ 40/ha to avoid deforestation would have the same impact as taxes – but would require US$ 2.5 billion per year of transfers to farmers (approximately 1.4 percent of the Brazilian federal budget for 2006).[11]

Taxes and payments are known as price instruments. They impose an extra cost on farmers when they deforest (tax) or an extra benefit when they do not deforest (payments). It is well known in the environmental literature that price instruments are cost-effective, i.e., they are able to achieve the target with minimum costs. The 20% limit, on the other hand, is a command-and-control policy. So, it should not be surprising that the 20% limit would have been more expensive than taxes and payments. The economic reason is simple. Under taxes, the more productive farms would use more than 20% of their land for agriculture and pay the corresponding taxes, while less productive farmers would use less land. The total agricultural land would be 20%. Under the 20% limit rule, on the other hand, more productive farmers would have to use less land than they would like and so would have forgone considerable profits. The forgone profits would not be compensated by the increased profits of the less productive farms that would use up to 20% of their land. The total forgone profits (i.e., the opportunity costs) of the 20% limit should therefore be higher than the corresponding values for taxes.

Using a similar argument, one can conclude that payments to avoid deforestation also would be more cost-effective than the 20% limit. An important problem with payments programs however is that they may pay farmers who would not deforest their land even in the absence of the programs. Ideally, only farmers that change their behavior would

[11] Tax revenues would have been approximately US$ 627 million per year (0.35 percent of the Brazilian federal budget for 2006). Instead of redistributing the tax revenues to farmers, the revenues could be used to pay for almost the total budget allocated to IBAMA and INPE together.

receive the money. But the program cannot know for sure who is going to deforest and who is not. According to my calculations, a perfectly targeted policy paying US$ 40/ha only to those who would deforest their lands, and not paying those who would not deforest, would have cost almost half the non-targeted program: US$ 1.2 billion per year. The difficulties and costs associated with this asymmetric information are far from negligible. Yet, payments would still be a better option than the 20% limit rule.

In addition to the differences in costs, the geographic pattern of land use also would be different under the different policies: deforestation under taxes and payments would be more concentrated in the South Amazon, arguably the most productive area. The forests in the center regions of the rainforest would have been less fragmented, which may be advantageous from a biodiversity point of view.

Taxes and payments also have implications for income distribution. Taxes put the costs of preservation on the shoulders of local farmers; while payments share the costs among those who benefit from preservation and give compensations to local farmers. However, if a payment program were implemented, most of the payments would be directed to the large farms because the land distribution is extremely unequal in Brazil – and in the Amazon in particular. Farms with more than 500 hectares are responsible for approximately half of the area occupied by private properties in the Amazon (according to the Agricultural Census of 2006), even though they are approximately 5% of the total number of farms. And private properties occupy almost 20% of the Brazilian Amazon rainforest. Policies targeting small landholders are therefore unlikely to promote significant conservation (and reduce local poverty simultaneously). Raising the money from taxpayers in Brazil and directing it to large farmers in the Amazon may be politically difficult.

Another possibility is to obtain funds from international sources – after all, the preservation of the Amazon provides global benefits. The payments for reduced emissions from deforestation and degradation (REDD+) agreements are an example that have been extensively discussed in the United Nations Framework Convention on Climate Change (UNFCCC).

II.b. Policy Interventions and Emissions of Carbon

To understand the implications of taxes and payments for carbon emissions – and the potential of the REDD+ agreements – we need estimates of the carbon stock in forested and deforested areas in the Amazon. Baccini et al. (2012) recently measured the geographic distribution of the aboveground carbon stock in Brazil. The Brazilian Amazon stores approximately 100 billion tons of carbon. I combined their map of carbon stock with the maps of deforestation from satellite images and computed for each municipality the difference of carbon stock in forested and deforested areas. Different municipalities may have different carbon stock in forests and in agricultural areas because forests are heterogeneous and the alternative land uses in agriculture may conserve more or less carbon on the ground. The average difference between the carbon stock in forested and deforested areas is 78 tons of carbon per hectare – smaller than the commonly used rule of thumb of 100 of tons of carbon per hectare. My calculations suggest that if a carbon tax of US$ 1 per ton of CO_2 per year were implemented, farmers would be willing to deforest less and, as a result, avoid the emissions of approximately 4 billion tons of carbon. The avoided emissions correspond to approximately 4.4 years of worldwide emissions from land-use change during 2002 to 2011 [IPCC (2013)].

A carbon tax of US$ 1/tCO_2/year is significantly smaller than the average price of carbon in the European Union Emissions Trading System. For example, by the end of 2012 the price was US$ 8.75/tCO_2. The difference in prices suggests substantial opportunities for trade, but such opportunities have not yet taken place. A possible reason lies on potentially large transaction costs. Measuring and monitoring the amount of carbon stocks is expensive. Perhaps more important, measuring avoided emissions depends on the counterfactual emissions that would occur in the absence of payments – which is controversial and not trivial to compute *ex-ante*.

To be optimal, both taxes and payments should reflect the marginal environmental benefits of the forested land. Because it is difficult to measure the production of all the externalities and to put a monetary value on the corresponding benefits, a lower bound on the optimal tax can be obtained from the estimated damages associated with an incremental change in CO_2 emissions. According to my calculations, Greenstone et al.'s (2011) carbon tax of US$ 21/tCO_2 would virtually eliminate the agricultural land in the Amazon.

The Amazon is responsible for 20% of the Brazilian agricultural area. If no land in the Amazon were used for agriculture, one should expect non-trivial impacts on the local economy, on Brazil's trade balance, and possibly on international prices of beef and soybeans. Increases in the prices of these products could diminish the welfare from consumption of food. In addition, more deforestation in other locations could occur, a problem known as "leakage". To the best of my knowledge, there has been no research trying to measure the potential “leakage” effect from avoiding deforestation in the Amazon. It would require estimating impacts on international prices – a task that only recently has been carefully addressed in the context of biofuel policies (see, for example, Roberts and Schlenker, 2013; and Scott, 2014; and the literature cited therein).

II.c. Benefits of Preservation Other than Avoided Emissions

My results are largely in accordance with Assunção et al. (2013): policies to prevent deforestation have great potential social benefits, even when considering monitoring costs or farmers’ opportunity costs. The calculation of benefits however only take into account the avoided carbon emissions. Protection of biodiversity is another benefit from preservation. While covering less than 10% of the Earth’s land surface, tropical forests are estimated to contain at least 50%, possibly 90%, of Earth’s total number of species. As natural habitats are destroyed and fragmented, the species disappear. Most extinctions today seem to occur in tropical forests (Montagnini and Jordan, 2005).

Tropical forests also influence local hydrologic regimes. Approximately 50% of the rainfall in the Amazon comes from condensation of water vapor from evapotranspiration from the forest canopy. A decrease in rainfall may result from deforesting large tract of lands as the remaining forest may be less able to evaporate and transpire (Salati and Nobre, 1992).

Changes in rainfall, by their turn, can affect forest resilience and agricultural productivity. Longo (2013) estimates how much shift in the rainfall regime at different areas of the Amazon forest could stand before the ecosystems experience major significant losses. Using an individual-based land ecosystem model (Ecosystem Demography model, ED-2.2) to simulate the plant community dynamics, he finds substantial biomass loss at modest rainfall reductions in a mid-Eastern Amazonia site, with the largest impacts on the larger trees.

Global effects of deforestation on rainfall are not yet entirely clear. Deforestation affects the surface albedo and aerodynamic drags, which in turn affect air circulation, temperature, cloudiness, etc. The feedbacks between the ecosystem and the atmosphere can affect the distribution of heat and rainfall within the Amazon, which can further affect the dynamics of the remaining forests. In addition, impacts on one location can influence heat and rainfall in other neighborhood locations. The global effects involve therefore a highly scale-dependent and non-linear system. It is still unknown how the Amazon forest will respond to the ongoing changes in climate, especially droughts, which are expected to become more frequent with the climate change.

Deforestation also affects soil erosion and fertility. When vegetation is removed, soil becomes less permeable and, as a result, there is more erosion and soil runoff during rainstorms. Flood become more common and water flow in streams decreases during dry seasons. The soil productivity may also be reduced in the already poor soils in the Amazon. Nutrients in rainforest ecosystems are retained primarily in soil organic matter. Once a forested area is cleared, the litter and humus on the forest floor and the organic matter within the soil disappear. As a result, the ability of the soil to recycle nutrients is quickly lost and the soil fertility declines (Montagnini and Jordan, 2005).

Measuring the impacts of deforestation on local biodiversity, local climate, soil erosion and fertility has been an immensely difficult task. Putting a monetary value in these impacts has been even more difficult. Nonetheless, the few existing results that I am aware of suggest considerable gains from preservation even in the absence these benefits.

II.d. Price Instruments in the New Brazilian Forest Code

Now that the monitoring capacity has been improving in Brazil, the government seems to be slowly moving in the direction of adopting price instruments. The new forest code, modified in 2012, introduced two new important elements: (a) the creation of the Rural Environmental Registry (CAR); and (b) the establishment of a transferable quota system for the 20% limit rule (Environment Reserve Quota). The Rural Environment Registry is a new public record compulsory for all landowners. All properties, and the geographical delimitation of the required protection areas, must be georeferenced. The monitoring and oversight of each farm will then be done by satellite images.

The transferable quota system is a price instrument – and is therefore a cost-effective policy. Farmers exceeding their 20% limit can buy quota from farmers using less than

20%. A quota market can therefore emerge. Deforesters will have to pay for the land use in the same way they would have to pay under taxes on agricultural land.

The quota system existed prior to the new forest code. However, the transfers were restricted to the same watershed, limiting the potential of the markets. Furthermore, the Provisional Decree 2.166/2001 that established the legal basis for the transferable quotas was never regulated. With the new code, the transfers can be done within the same biome, which increases the potential market gains. The question that remains now is whether the quota market is going to take off or not. If it does, combined with the Rural Environmental Registry and the satellite-based monitoring, it will be a significant step in increasing the efficiency of the Brazilian environmental regulation and in improving worldwide social welfare.

Deforestation has slowed down. Now is time to concentrate efforts to make the policy interventions more efficient.

References

Assunção, J., Gandour, C. and Rocha, R. (2012) "Deforestation Slowdown in Legal Amazon: Prices or Policies?" Climate Policy Initiative Working Paper Series.

Assunção, J., Gandour, C., Rocha, R. and Rocha, R. (2013a) "Deforestation Slowdown and Rural Credit Policies in Brazilian Amazon" Climate Policy Initiative Working Paper Series.

Assunção, J., Gandour, C. and Rocha, R. (2013b) "DETERing Deforestation in the Brazilian Amazon: Environmental Monitoring and Law Enforcement" Climate Policy Initiative Working Paper Series.

Baccinni, A., S. J. Goetz, W. S. Walker, N. T. Laporte, M. Sun, D. Sulla-Menashe, J. Hackler, P. S. A. Beck,R. Dubayah, M. A. Friedl, S. Samanta and R. A. Houghton (2012) "Estimated Carbon Dioxide Emissions from Tropical Deforestation Improved by Carbon-Density Maps," *Nature Climate Change* 2, 182-185.

Chimeli, A. and R. G. Boyd (2010). "Prohibition and the Supply of Brazilian Mahogany." *Land Economics*, 86(1), 191-208.

FAO (2010). *Global forest resources assessment, Main Report*. FAO Forestry Paper 163, Rome.

Greenstone, M., E. Kopits, and A. Wolverton (2011). "Estimating the Social Cost of Carbon for Use in U.S. Federal Rulemakings: A Summary and Interpretation," NBER Working Paper Series, w16913.

Hirakuri, S. R. (2003). Can Law Save the Forest? Lessons from Finland and Brazil. Jacarta, Indonesia, Centre for International Forestry Research.

INPE, Instituto Nacional de Pesquisas Espaciais (2013), *Monitoramento da Floresta Amazônica Brasileira por Satélite – Projeto Prodes*. Available at: http://www.obt.inpe.br/prodes/

INPE/ TerraClass, Instituto Nacional de Pesquisas Espaciais (2013). Available at: http://www.inpe.br/cra/projetos_pesquisas/terraclass2010.php

IPCC (2007). *Climate Change 2007: The Physical Science Basis*. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

IPCC (2013). *Climate Change 2013: The Physical Science Basis*. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Longo, M. (2013). *Amazon Forest Response to Changes in Rainfall Regime: Results from an Individual-Based Dynamic Vegetation Model*. Ph.D. Thesis, Harvard University, Department of Earth and Planetary Sciences. Available at: http://nrs.harvard.edu/urn-3:HUL.InstRepos:11744438

Montagnini, F. and Jordan, C.F. (2005) *Tropical Forest Ecology: The Basis for Conservation and Management*, New Haven: Springer

Roberts, M. J. and W. Schlenker (2013). "Identifying Supply and Demand Elasticities of Agricultural Commodities: Implications for the US Ethanol Mandate," *American Economic Review*, 103(6), 2265-2295.

Salati, E and C. A. Nobre (1992) "Possible Climatic Impacts of Tropical Deforestation," *Climatic Change*, Volume 19, Issue 1-2, 177-196.

Scott, P. T. (2013) “Dynamic Discrete Choice Estimation of Agricultural Land Use,” Mimeo, Toulouse University.

Souza-Rodrigues, E. A. (2014) “Demand for Deforestation in the Amazon,” Mimeo.

TCU, Tribunal de Contas da União (2009). "Arrecadação de multas administrativas - Exercício de 2009". Available at: http://portal2.tcu.gov.br/portal/page/portal/TCU/comunidades/contas/