Does Amazonian land use display market failure? An opportunity-cost approach to the analysis of Amazonian environmental services

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Abstract

The article discusses whether deforestation in the Amazonian region should be considered a typical case of market failure and computes the opportunity cost of economic activities that promote deforestation relative to uses that keep the forest intact. For environmental resources threatened by Amazon deforestation, forms of productive land use ("opportunity" uses) are considered in terms of the net benefit values of primary land-based activities. The accounting exercise conducted in this study calculates the net benefit per hectare obtained from the direct use value (DUV) for different land use alternatives (timber, non-timber, livestock and agriculture); the indirect use value (IUV) related to carbon storage; and the non-use value (NUV) (existence value). The results show that the opportunity cost of deforestation in 2009 was positive for the most common land use, livestock activity. Such findings indicate a market failure. Nonetheless, this is not the only possible outcome when considering alternative land uses.

Keywords

Deforestation, forest degradation, economic aspects, costs, cost-benefit analysis, land use, agriculture, livestock industry, silviculture, environmental economics, environmental management, Brazil

JEL classification

Q57, Q23, O13

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I. Introduction

The traditional economics literature suggests that most environmental assets have no substitutes and that the absence of a "benchmark price" for their services distorts economic agents' perceptions of their value. In practice, as these assets have public good characteristics, a large proportion of the ecosystem services obtained by consumers cannot be captured exclusively by the agent that pays for the good. This distortion leads to market failure in terms of efficient allocation (Stiglitz, 2000), which in turn reveals a divergence between private and social costs (Pigou, 1932). Accordingly, the "prices" of environmental resources must be estimated to provide a technical foundation for their rational exploitation. This is typically based on environmental economic valuation methods (or techniques) grounded in neoclassical welfare theory (Pearce, 1976; Pearce and Turner, 1990; Kahn, 2005). One approach derives from the concept of opportunity cost applied to environmental conservation (Pearce and Markandya, 1987; Warford, 1987).

The strictly economic concept of opportunity cost defines opportunities foregone relative to the best use of certain economic resources, which confronts an efficiency concept (best use) with a resource scarcity concept. Nonetheless, in today's ecological context in which natural resource is considered critical, the opportunity cost concept and the method derived from it evaluate the income loss resulting from the constraints imposed on the production and consumption on private goods and services by measures to conserve or protect environmental resources. In the case of environmental resources threatened by deforestation, various forms of land occupation and productive land use are considered as "opportunity" uses (May, Veiga Neto and Chévez Pozo, 2000); and the opportunity costs represent the extractive land use of highest value (Naiddo and others, 2006).

In this connection many studies of the value of the Amazonian ecosystem have estimated the economic value of resources and environmental services from the standpoint of specific economic agents. Instead, this article aims to evaluate the net benefits for the region's main land-use activities (timber forest products, non-timber forest products, livestock and agriculture), viewing the productive uses of these net benefits as in direct competition with keeping the forest intact, and, consequently the net benefit that arises from "unproductive" uses (such as net benefits of carbon stocks, forest existence value).

Section II of this article discusses the main environmental services provided by the Amazon forest. Section III then builds on this by considering earlier studies that have attempted to value the Amazon's environmental goods and services. Section IV describes the methodological procedures adopted by the study, along with its results; and the concluding section provides some final thoughts.

II. Ecosystem services provided by the Amazon forest

Ecosystem services, along with their ecological processes, may be considered a subset of ecosystem operational structures (DeGroot, Wilson and Boumans, 2002). Moreover, these are not direct benefits, but inputs (Boyd and Banzhaf, 2007; Fisher and Turner, 2008; Fisher, Turner and Morling, 2009). They become services when they affect people's well-being (Fisher, Turner and Morling, 2009).

In the Amazon basin,[1] ecosystem services have a special impact because of the interconnections between the Amazon rainforest and the global climate system, owing to their function in carbon storage

[1] Amazônia Legal is a political-administrative division that encompasses the entire Amazon biome, areas of the Cerrado (Brazilian savannah) and natural grasslands, extending for 5 million km^2, or approximately 59% of all Brazilian territory. It span all of the northern Brazilian states (Acre, Amazonas, Amapá, Pará, Rondônia, Roraima and Tocantins) along with Mato Grosso and part of Maranhão (Pereira and others, 2010).

and sequestration (Nobre, Sellers and Shukla, 1991).[2] As a result, the planet´s climate balance becomes a function of the integrity of the Amazon rainforest. Moreover, the healthy functioning of the ecosystem throughout the basin sustains a wealth of biodiversity, which is of critical importance to the world's biological resources. With the Amazon supporting from 10 to 20 percent of global biodiversity, this maintenance function represents a valuable ecosystem service to the world community (Kaplan and Figuereido, 2006; Lopes, Nass and Melo, 2008).

At least 40,000 plant species, 427 mammals, 1,294 different types of bird, 378 species of reptile, 427 amphibians and 3,000 fish species are estimated to inhabit the Amazon rainforest biome (Rylands and others, 2000). A recent study by the World Wide Fund for Nature (WWF-Brasil, 2010) shows that between 1999 and 2009 approximately 1,220 new plant and vertebrate species were found in the biome, including 637 plants, 257 fish, 216 amphibians, 55 reptiles, 16 birds and 39 mammals. Furthermore, six Natural Heritage Sites and elements from 56 Global Ecoregions are partly or fully embedded in the Amazon rainforest biome, according to the classification adopted by the United Nations Educational, Scientific and Cultural Organization (UNESCO). Over 600 different types of terrestrial and freshwater habitats are also found in this biome, which encompasses large endemic areas with native species that are not found anywhere else in the world.

In addition to sustaining biodiversity, Amazonian ecosystems provide important support services in the global water cycle and carbon sequestration. Together, these services make the region a "global commons resource" (Dasgupta, 1990; Grafton and others, 2004). In the case of water, they represent a global public good (Kaul, Grunberg and Stern, 1999; Kahn, 2005).

The Earth's rotation enables winds to circulate from the northeast and enter the region, carrying water vapour from the Atlantic Ocean that falls as rain. This rain is then partly recycled by the trees through evapotranspiration (Fearnside, 2004). An estimated 10×10^{12} m^3 of water enters the region annually through trade winds. The annual water flow into the Amazon river totals 6.6×10^{12} m^3 (Salati, 2001), while the remainder, 3.4 x 1012 m^3, is transported to other regions. Annual rainfall across the basin is estimated at between 1,350 and 1,570 mm, which corresponds to between 63% and 73% of the annual rainfall caused by the water evapotranspiration phenomenon in the region (Costa and Foley, 2000; Marengo and Nobre, 2001; Malhi and others, 2008).

In terms of carbon sequestration, tropical forests play a key role in the global carbon cycle, because they store a large amount in both the above- and the below-ground biomass. The Amazonian forest biomass is estimated to hold approximately 70 PgC (petragram of carbon), which corresponds to 10%–15% of the Earth's total carbon stock (Keller, Melilloand Zamboni de Mello, 1997; Houghton and others, 2001). Other studies, such as Saatchi and others (2007) have reported total carbon stock values, including dead and below-ground biomass, ranging from 77 to 95 Pg C, with a mean of 86±17 Pg C. Currently, the Amazon biome seems to be functioning as a carbon sink, absorbing between 0.44 and 0.56 Pg of carbon per year (Grace and others, 1995; Phillips and others, 1998; Malhi and others, 1998).

Although biodiversity maintenance, water recycling, and carbon sequestration are some of the most important ecosystem services provided by Amazonia, there are others such as fire protection and reduction of pathogens/diseases by controlling organisms (Foley and others, 2007). Although timber provides high-value market goods, the provision of non-timber forest products should be interpreted as a direct form of ecosystem service, sometimes with a market value (for example the Brazil nut). The wealth of the Amazon basin includes a timber volume of approximately 106.388 billion m^3 with an above-ground biomass stock of 92.203 billion tons and a below-ground biomass stock of 13.367 billion tons (84.2 and 65.1 million tons in Brazilian territory, respectively (SFB, 2010)).

[2] Nonetheless, in contrast, the threshold carbon release caused by tropical deforestation is not yet known in terms of its potential effect on continent-scale climate change, or if such a change really will take place at all (Stickler and others 2009).

Land-use changes in the Amazon region have been associated with fire and deforestation. Data from the TerraClass project (Embrapa/INPE, 2012) ahow that, by 2010, cattle ranching was already using 45.9 million hectares, occupying 66% of all deforested areas, while annual agriculture occupied 5.4% (about 4 million hectares).

Deforestation in the Amazon region is estimated to have emitted very large amounts of carbon into the atmosphere. During the peak of deforestation in the 1990s, the region may have emitted between 0.8 and 2.2 Pg C, which would represent about 10%–15% of global greenhouse gas (GHG) emissions in the period (Houghton, 2005). Accordingly, the continuation and intensity of deforestation have severe consequences for ecosystem functions in the Amazon basin (Foley and others, 2007), and could even affect rainfall in the region (Salati and Nobre, 1991; Sampaio and others, 2007; Nobre and Borma, 2009).

When considering the importance of Amazonian ecosystem services,[3] the benefits can be measured on local, regional, national, and global scales. Local beneficiaries are directly affected by the conflict between productive and unproductive land use. Regional beneficiaries are the residents of the region, which includes the first group of local beneficiaries but also those who do not compete for land use. National beneficiaries encompass all those who receive some sort of benefit within the country's borders, thus including the two previous categories. Lastly, global beneficiaries include those who receive benefits beyond the country's borders, arising from the non-excludable and non-rival characteristics of the Amazon ecosystem's "global commons" or "global public goods". Accordingly, they also encompass the aforementioned beneficiary categories.[4]

When beneficiaries are viewed from this perspective, there is a danger of double-counting. For example, local beneficiaries can enjoy direct-use benefits such as the supply of timber and non-timber resources; but they can also enjoy the benefits of other ecosystem services, such as regulation of carbon sequestration, which has (global) public goods characteristics. In contrast, the decision on whether to use the land productively or conserve the forest imposes a direct opportunity cost upon local economic agents, who may who fail to earn income as a result of the land use choice —in other words when conservation ("unproductive use") is chosen. Thus, for local beneficiaries, alternative forest uses, including deforestation to clear the way for different types of use, such as crop farming or livestock, compete with each other in terms of the potential income generated (benefits).

III. Review of literature on the valuation of Amazonian environmental goods and services

Researchers have started to study the economic values of the tropical forest, considering both its productive uses and its ecological values. This section reviews research on Amazonian deforestation. While the various studies use different methodologies, all agree that large-scale loss of the Amazonian biome represents a significant cost, as shown below. Annex table A1.1 summarizes the main studies and findings on Amazon ecosystem services valuation.

Various studies have put a value on Amazonian ecosystem services. Some attempt to assign a general value, or total economic value, to these services as whole (Andersen, 1997; Torras, 2000), while others attempt to value specific environmental services or resources only. The latter consider different spatial scales and report values for different years, which makes then difficult to compare.

[3] Anderson-Teixeira and others (2012) stress the significant role of terrestrial ecosystems in climate regulation through biophysical mechanisms (regulation of water and energy) and biochemical ones (regulation of greenhouse gases). Biogeochemical factors, land use change and agriculture jointly account for over 25% of global greenhouse gas emission. About 40% of gross CO_2 was emitted from deforestation in tropical forests between 1990 and 2007.

[4] An analysis of these features and how they may change in the case of ecosystem services goes beyond the remit of this article. For a discussion see Fisher, Turner and Morling (2009).

IV. Market failures and the opportunity cost of Amazon land use

1. Market failures

There are various sources of market failure related to land use in the Amazon, which result in deforestation across the region. One source of market failure, which can be considered prior to the land-use decision, stems from incomplete or imperfect information on land conversion opportunities. Agents are ignorant of most ecosystem services, such as support services, and regulatory and cultural services. Keeping the forest intact implies the need for such services; so the "landowners" would not capture the benefits (Kahn, 2005).

Another ex ante source of market failure stems from the inadequate definition of land rights in the region. On this point, Panayotou (1993) argues imprecise, or even non-existent property rights, compounded by the high transaction costs associated with environmental conservation, could also be viewed as sources of additional local market failures. They create a sense of free access to forest and land. These two sources of market failures are linked to very high transaction costs in the region: enforcement costs, stemming from lack of secure property rights (or contract enforcement); and measurement costs, arising from uncertainty arising from the incomplete and imperfect information on which economic decisions are based (Williamson, 1985).

For Pearce (1998), on the other hand, the deforestation process combines three "economic failures": failure of government intervention, failure of the local market, and failure of the global market. The first occurs as a result of government intervention. By creating infrastructure and direct and indirect mechanisms to sustain the profitability of "local" productive activity, government intervention artificially widens the gap between private costs and social costs, thus further fuelling the conversion of the forest into other forms of land use.

The other sources of failure stem from the externalities imposed by deforestation on the directly affected local population, including the land-use opportunity cost, and indirect effects on the population living outside the region's borders, who will lose the benefits of ecosystem services destroyed by deforestation. In practice, market failures lead to a rate of forest conversion that may be privately profitable but not socially optimal.

2. Opportunity costs

Opportunity costs measure what could have been achieved by using a resource in an alternative use. In protected land areas, the opportunity cost is typically the highest-value extractive land use (Naidoo and others, 2006). Pearce and Markandya (1987) suggest that opportunity costs can be partitioned into three components: (i) the direct cost of the activity, including the cost of labour and materials used in the extraction of natural resources; (ii) external costs imposed on a third party; and (iii) intertemporal costs related to possibilities for its future use or non-use. This classification is similar to that proposed by Warford (1987), who states marginal opportunity cost would ideally equal the price users would have to pay for resource-using activities. Thus, the opportunity cost of using and maintaining an environmental resource is measured as its net benefits (gross income minus production costs) under the predictable activity. This article considers two perspectives: the opportunity costs of deforestation and the opportunity costs of conservation (the same value with opposite signs).

V. Cost-benefit analysis of maintaining environmental goods and services provided by the Amazon

1. Methodological procedures

Deforestation costs offset the benefits of this process measured by gain obtained from the various alternatives for Amazonian land use, mainly logging, livestock farming, and both seasonal and perennial agricultural activities. In addition to those direct-use benefits, the value of indirect use of the Amazon forest is estimated on the basis of its carbon storage value and its existence value, according to previously published studies.

The net benefits (NB) yielded by the goods and services in question provide a good measure of the opportunity cost (OPC) of keeping the forest intact. So, the general rule of the valuation exercise developed adopts the following economic rationale:

$$NB\ DU\ (direct\ use) + NB\ IU\ (indirect\ use) - NB\ NU\ (non\text{-}use) = TEV\ (total\ economic\ value) \quad (1)$$

But,

$$OPC\ D\ (deforestation) = (NB\ IU + NB\ NU) - NB\ DU \quad (2)$$

or

$$OPC\ C\ (conservation) = NB\ DU - (NB\ IU + NB\ NU) \quad (3)$$

So,

$$OPC\ C = -\ OPC\ D \quad (4)$$

This logic is based on the hypothesis that net benefits are equivalent to their respective net returns, which may be estimated through the differences between the respective values of gross production and costs. Thus, the opportunity costs of maintaining or deforesting the Amazon forest are equivalent to the net benefits resulting from the use of environmental goods and services. This study values those “opportunity uses” in terms of direct use (DU), or land use (timber extraction + non-timber extraction + livestock farming + agriculture). These are taken to mean effective land use and have the opposite sign to the indirect use (IU) (carbon storage), and non-use (NU) or existence value (EV), according to previously published studies.

Three additional observations are worth making. The first considers the heterogeneity of Amazonian pastures and requires the direct use of land in different grassland formations in the region to be calculated, as another approximation to livestock opportunity cost. Second, the deforestation scenario follows the economic rationale that expects that OPC C to be positive if NB DU is greater than NB IU + NB NU. Third, an output OPC D that is positive means that leaving the land forested yields greater value than alternative land uses. In this case, continuing the deforestation process represents a huge market distortion.

2. Net benefit calculations

(a) Net benefit of direct use (NB DU)

(i) Timber

The area of timber exploited in the Amazon is unknown, although estimates range between 10,000 km² and 20,000 km² per year (Barreto and others, 2005). In 2009, 13 million m^3 of native lumber were produced in the seven states of Amazônia Legal. This would give an estimated 9.46 m³/ha of timber, equivalent to a gross production value of R$ 802/ha (1,203,000,000/1,500,000), assuming a mean of 15,000 km² (1.5 million hectares) of timber exploitation in the region. In 2009, the mean production cost[5] of timber per cubic metre was R$ 143.84/ha. The mean cost of logging operations (felling, bucking, skidding and loading logs on trucks) was US$ 31 or R$ 61.7/m³; the mean cost of processing timber was US$ 41 or R$ 81.6/m³ (Pereira and others, 2010); and the mean transportation cost[6] per type of surface in the Amazônia Legal (river transport, paved highways and dirt roads) was US$ 0.23 or R$ 0.46/m³, which corresponds to R$ 0.54/m^3 at 2009 prices. Thus, the Net Benefit of production, calculated as net production value = gross production value (R$)/ha —mean production cost (R$)/ha, would equal R$ 802/ha— R$ 143.84/ha = R$ 658.16/ha.

(ii) Non-timber forest products (açaí berry and palm heart)

The açaí berry is an example of a non-timber forest product, not only for its strong presence in the local market, but also because the açaí fruit has been used in many ways in several industries, including cosmetics and personal hygiene, pharmaceuticals and medical, food and beverages industry. This makes the açaí berry a key representative of how Amazonian biodiversity generates products with various economic applications. Possibly the most popular example of its applications and is fresh and lyophilized pulp, and powdered or dry açaí.

Brazilian açaí fruit production totalled 115,947 tons in 2009, with the main producing state, Pará, accounting for 87.4% of national production, or 101,375 tons. This had a production value of R$ 145.4 million in 2009 (IBGE, 2010), and representing R$ 166.4 million for the Amazon.

A study conducted on the island of Cumbu in Belém, in the state of Pará, to estimate the cost of açaí production during harvest (from June to October) estimates total expenditure[7] for a mean daily production of three 28-kg baskets at R$ 40.53. Thus, the production cost for the four-month harvest period would be R$ 4,863.60 (10 tons of açaí berry; Pinto and others, 2010). If the total production cost of 10 tons of açaí berry was R$ 4,863.60, then the total cost of the 101,375 tons produced in Pará state is approximately R$ 49.3 million, corresponding to roughly R$ 56.4 million for the Amazon as a whole. Thus, the net production value (R$ 166.4 million minus R$ 56.4 million) would be approximately R$ 110 million.

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5 Average exchange rate in 2009: US$ 1.00 = R$ 1.99 (BCB, 2009).

6 The average transportation cost is the average of the confidence intervals defined for the mean transportation costs (5% probability level, n-1 degrees of freedom) reported in Lentini, Veríssimo and Pereira (2005) and aligned to the average exchange rate prevailing in 2009.

7 Daily labour cost (R$ 30.00); a materials depreciation cost of R$ 1.53 per day of use; and a cost of transportation of açaí to the point of sale (port) of R$ 9.00 (Pinto and others, 2010).

The açaí palm tree is the most commercially abundant tree with uses both in the floodplain forest and in the lowlands, occupying approximately 10,000 km^2 (one million hectares) of the Amazon estuary (May, Veiga Neto and Chévez Pozo, 2000). Based on these figures, the net production value of açaí berry divided by the planted area of this plant species (in hectares) gives a value of R$ 110/ha.

Pará State also accounted for 96% of Brazilian national output of palm hearts in 2009, producing 4,897 tons, for a value of R$ 6.9 million (IBGE, 2010). Thus, this quantity will be taken as the reference value for the Amazon.

The financial analysis of a palm heart factory in Pará producing 30 tons of palm hearts per month (Pollak, Mattos and Uhl, 1996), reported a mean monthly cost of raw material (large, medium and small palm hearts) of US$ 4,302, equivalent to R$ 12,960.49, and a monthly production cost (wages, chemical products, maintenance, freight, firewood, boat, energy and depreciation) of US$ 3,086 or R$ 9,297.09 when converted into Brazilian reais at the 2009 exchange rate. So, the total production cost[8] of palm heart produced in 2009 would be R$ 741.92 per ton. The final production cost would be R$ 3.6 million, assuming an output of 4,897 tons of palm hearts in 2009. The net production value of palm hearts (R$ 6.9 million minus R$ 3.6 million) would be R$ 3.26 million or R$ 3.26/ha.

(iii) Livestock farming

Livestock breeding in the Amazon region is typically extensive, with beef production predominating. This activity is responsible for the greatest change in land use in the Amazon, accounting for over 2/3 of the deforestation that has occurred in recent decades. In the last twenty years, the size of the cattle population has almost tripled (IBGE, 2012), with an expansion driven by factors such as currency devaluation and improved animal production and tracking systems, which led to the eradication of foot-and-mouth disease (Nepstad and Stickler, 2008). Beyond that, other features of the process in the last three decades include the increasing replacement of natural pastures by cultivated pastures and an increase in the pasture stocking rate to above the Brazilian national average (Valentim and Andrade, 2009).

Furthermore, between 2001 and 2010 there were also increases in the size of cattle herds, slaughter rates (ratio of the number of slaughtered cattle to the size of the herd) and meat production, or what is effectively used from the animal by weight (Agra FNP, 2010). The first two indicators rose by nearly 60%, while the third increased by about 30%.

Table 1 reports the annual cost and annual income (net benefit per hectare of beef cattle production) for selected municipalities in the States of Pará, Tocantins and Mato Grosso. Thus, the mean of those cost values and the net benefit per hectare, of R$ 100.62/ha, is taken as the reference value.

The dairy cattle herd in Amazônia Legal in 2009 was approximately 6.06 million animals according to 2010 estimates (Agra FNP, 2010). In the same year, the region produced 2.7 billion litres of milk, for