Impacts of Brazilian Amazon Protected Areas on Human Migration:

a mechanism behind deforestation-reducing local spillovers from protection

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Abstract (133 words)

Evidence is growing that spatial spillovers from conservation policies can be significant − potentially greatly affecting total impact − and can vary across landscapes, even in sign. That variation motivates theoretical and empirical study of land use within such settings. For the Brazilian Amazon, an evolving frontier with a great deal of tropical forest, here I try to explain a prior result that protected areas (PAs) lowered deforestation rates nearby. Given migration's importance throughout the history of this forest frontier, I ask whether dissuading migration could be a mechanism for protection's local conservation spillovers. Examining individuals' (non-) migration decisions among municipalities in the Amazon, I find that Federal PAs − previously seen to reduce rates of deforestation nearby to PAs − seem to be encouraging outmigration from and discouraging migration to PAs' locations.

Keywords: Brazil, Amazon, forest, protected area, migration, spillover

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1. Introduction

As both standard and novel efforts to conserve forests increase, including within climate policy[1], understanding their impacts is increasingly important. Many will occur in developing countries and thus conservation's multiple interactions with development processes are critical for thinking about not only what is optimal, locally or globally, but also how desired change can come about. Here I focus upon one particular way in which development may respond to conservation, and influence its impact, in examining whether protection in the Brazilian Amazon affects migration.

Within climate policy, global actors may wish to reward forested countries for lowering deforestation given credible evidence that the emissions from forests fell below agreed baselines. Such calculations should consider all of the impacts from a policy, including spatial spillovers, and net outcomes from carbon-market investments are likely to be scrutinized relatively closely. A lack of convincing evidence concerning net impacts could be grounds to ignore tropical forest as a source of emissions reductions. Alternatively, a sense of how forest spillovers might unfold could lead to an agreed basis for adjusting transfers, e.g., ex-post after spillovers are quantified.

I examine how Amazonian migration responds to different types of protected areas (PA), the dominant conservation policies. Rigorous evidence on their deforestation impact is limited, with even less linking development to impact variations. Very little evidence exists on spillovers − forest or socioeconomic − from PAs. Given such limited empirical evidence, and its value for conservation planning, here I aim to provide novel empirical evidence concerning whether the migratory responses of individuals to conservation is an issue actors should consider in planning. My results ideally could help to inform planning and contractual discussions for climate policies.

[1] PA initiatives for species also will continue. The Convention on Biological Diversity's Work Program on Protected Areas or "2010 targets" (www.cbd.int/protected/targets.shtml), e.g., suggests ongoing expansion of protected areas.

In general, PAs' total impacts involve not only land in PAs but also any spatial spillovers, i.e., any responses to PAs that could influence forest and socioeconomic outcomes elsewhere. Few question that spillovers could be important for total impact. Yet few study them empirically. Spillovers include local 'leakage', for example a rise in deforestation near PAs, and leakage that is global if, as restrictions upon relevant supplies, PAs raise some global prices for commodities.

Previous deforestation spillovers evidence, e.g. for Costa Rica and the Brazilian Amazon, focuses on where local forest spillovers might occur and determining their signs and magnitudes. Results for Brazilian Amazon PAs (Pfaff et al. 2014a) suggest avoidance of nearby deforestation, that is, lower deforestation around some PAs than would have been expected without any policy (more for Federal and Sustainable Use PAs than others). These results stand in sharp contrast to Costa Rica (Robalino et al 2012), where leakage is observed when near both PAs and roads but far from a park's entrance. Yet a more general point − the signs and magnitudes of net spillovers depend on land-use contexts within local development baselines − holds for both these countries. That motivates consideration, by setting, of mechanisms implied by private and public responses.

One critical private response to a new PA in a region is a shift in migration in response to expected shifts in jobs and income opportunities. One critical public response could be changes in current or planned infrastructure investments to raise employment and output − for example, a transport ministry could reduce road creation and maintenance (e.g., as one agency is playing off against another within an administration). Deferred maintenance, e.g., may result from lower expectations of development impacts, which in turn can result from expectations of migration. Those migration responses, however, could depend on households' expectations of maintenance. Critically, all these decisions are likely to depend heavily on expectations of future behavior and, within such a setting, public establishment of a local conservation policy can function as a signal.

Leaving 'theory' there, for the current reduced-form exploration of migration due to PAs, below I examine empirically the linkage to frontier migration from PAs in the Brazilian Amazon. I combine geographic (pixel) data on spatially specific land characteristics, and forests over time, with socioeconomic (micro) data from the 1991, 2000 and 2010 Brazilian Census as well as the 2006 Agricultural Census, including individuals' characteristics and recent migration decisions. Merging such data permits me to examine determinants, including PAs, of individuals' 2005-10 (non-) migration across locations in the Brazilian Amazon. To test the impacts of recent changes, I examine effects of PAs created during 2000-04, prior to the period of migration that I consider.

First I study the outmigration in a binary logit model using characteristics of individuals and their current locations. Education, employment sector and gender, e.g., are known to be significant factors in outmigration. Critically, PA locations are known to often be biased along such dimensions. As that can affect outcomes of interest, to at least partially address endogeneity I employ not only multivariate regressions but also matching, as a pre-processing of my sample, before redoing my logit regressions. This step forces greater similarity across sites with high and low PA fractions. To examine how the characteristics of both origin and destination locations affect the choice of MCA during 2005-2010, I also implement a multinomial (conditional) logit.

The logit suggests PA impacts on outmigration consistent with deforestation spillovers. Most specifically, Federal PAs, previously found to reduce nearby clearing, appear to encourage individual outmigration. Moreover, the multinomial logit shows that they reduce the likelihood of inmigration. Federal actions appear to have greater ability to affect the relevant expectations.

Below, Section 2 reviews empirical and theoretical literature relevant to PAs' impacts, while Section 3 presents the study area, the data that I will analyze, and my empirical strategy. Section 4 then provides my results, followed by the discussion of all of my results in Section 5.

2. Protected Areas, Spillovers & Migration

2.1 Protected Areas' Forest Impacts

As highlighted by Pattanayak et al (2010) and Joppa and Pfaff (2010), at least two fundamental issues often confound evaluation of PA impacts. One − a central motivation here − is that PAs can generate forest spillovers, such that total impacts differ from impacts within the boundaries of those PAs. In principle, this is widely acknowledged. In practice, in most evaluations it is not.

Robalino and Pfaff (2012), in considering spatial interactions within private deforestation decisions through the use of neighbors' slopes to instrument for neighbors' land-use decisions, note there are many possible sources of interactions between neighboring land uses. That applies to interactions between public neighboring land uses, e.g., between PAs and forested land-use decisions nearby that might respond to public land use. For instance, reduced crop production on protected lands could deflect demand to lands nearby and, as a result, increase production and clearing in the nearby forests. Alternatively, establishing a PA can attract tourism, increasing the private returns to retaining forest to engage in the tourism sector (instead of clearing to produce).

Empirical evaluations of interactions can be confounded by a second fundamental issue, that the locations of PAs often are not distributed randomly across the landscape but have a bias. Relevant for my study of local forest spillovers, that means lands near PAs also are not random, i.e., they might be expected to differ from unprotected lands in ways relevant for deforestation. The effects of this can be seen in evidence on the impacts of protection upon forests within PAs. Most evaluations have not explicitly measured the characteristics of protected lands in generating the baselines to which PAs are compared in order to infer PAs' impacts. As a consequence, since PAs are biased towards low pressure (Joppa and Pfaff 2009), PA impacts often are overestimated (see, for instance, Andam et al. 2008 for Costa Rica or Joppa and Pfaff 2010 for a global study).

My previous work (with others) concerning PAs in the Brazilian Amazon also considers impacts on deforestation within PA boundaries, for Acre State (Pfaff et al 2014b) and the region (Pfaff et al. 2014c, d). Using randomly selected pixels with detailed geographic data, two main categories of protection are compared, Integral Protection areas and Sustainable Use areas, either of which could be implemented at the Federal or at the State level. As I do here, that work aims to reduce potential estimation biases using matching methods (Rosenbaum and Rubin 1983), i.e., by explicitly seeking to compare treated (protected) areas to untreated locations that are similar in terms of the characteristics that are expected, and are shown, to be relevant for deforestation. This approach halves estimated impacts versus 'apples to oranges' comparisons, while revealing considerable variation in PA impact (taking as a given that most of these PAs are well enforced). Further, it appears as though the political economy of PA location permits Sustainable Use areas, whose governance allows some local deforestation, to be closer to clearing threat and thus block more deforestation than Integral areas that ban clearing but seem feasible only far from threats. The same is true of Federal PAs, which are higher in pressure, and thus impact, than State PAs.

Again with others, I evaluate local forest spillovers from PAs in the Brazilian Amazon (Herrera et al. 2015), using matching as land near PAs is likely to have location biases PAs do (see Figure 1). Comparing the deforestation nearby to PAs to that on unprotected lands that are observationally similar but far from PAs suggests lower-deforestation 'halos' around some PAs. That is, there was less deforestation around those PAs than expected if the PA were not to exist. Further, and consistent with the impacts within these PAs, these spillover effects were larger and more significant around Federal and Sustainable Use PAs than around the other types of PAs. Such a 'halo' contrasts with 'leakage', i.e., more deforestation, near Costa Rican PAs (Robalino et al 2012) near roads but far from PA entrances − which follows from different land-use dynamics.

2.2. Potential Spillover Mechanisms

To my knowledge, no study provides evidence on migration underlying forest impacts from PAs outside of their boundaries, which could have environmental and socioeconomic implications even quite far from where protection is implemented. The importance of studying population dynamics, including migration, and their relationships to conservation is noted by Joppa (2012). As human populations around the world have also grown exponentially, increased numbers live close to PAs, generating greater anthropogenic pressure on them. However, it is less clear how the existence of the PAs has influenced human activity near PA borders. Understanding such interactions between development patterns and conservation is important for guiding not only the most effective conservation but also ways to address concern for rural development and welfare.

Few empirical studies attempt to show mechanisms through which conservation policies affect social and environmental outcomes outside their boundaries. Ferraro and Hanauer (2014) present a framework to explore how PAs might affect poverty in Costa Rica. They focus on three mechanism: changes in tourism and recreational services; changes in infrastructure such as road networks, health clinics and schools; and changes in regulating and provisioning ecosystem services and forgone production activities that arise from land use restrictions. They find that the major part of the poverty reduction associated with the creation of PAs in Costa Rica is causally attributable to tourism activities. Robalino and Villalobos (2014) also provide evidence that such impacts of PAs in Costa Rica are due to tourism, including through the idea of tracking the location of PA entrances, while Sims (2010) provides some related evidence for Thailand.

For the case of the Brazilian Amazon in recent decades, I hypothesize that the creation of a PA could serve as a signal of a change in the local/regional development path that could affect both private migration and public road building − which also will affect each other. In a frontier setting such as the Brazilian Amazon, where most of the PAs have not featured a lot of tourism development, the establishment of PAs by a public authority may signal to a number of parties that there will be fewer subsidies to local economic development than previously were expected. Such a signal could discourage migration, as well as building and maintenance of roads nearby.

Taking each of these potential responses in turn, private migration choices are thought to respond at least in part to changes in individual expectations of employment and income in each candidate migration destination (including the current location, i.e., should one just not migrate). The establishment of a PA may well signal that within the relevant political economy, forces in favor of conservation have gained traction relative to the forces of economic development. If so, then one might well lower one's expectations of standard frontier development investments (e.g., schools or health posts). That provides a rationale for a migrant to lean away from the PA's area.

Moving to potential public responses, creating a new road or maintaining an existing road or improving (e.g., paving) it are ways to pursue the general goal of economic development. Consider, for instance, the decision to maintain a road. That may not seem worthwhile if other factors have limited migration since, if nobody will use the road, resources should go elsewhere. Indeed, in the Brazilian Amazon roads have gone to ruin when initial investments did not lead to a high usage − seemingly lowering development expectations and clearly lowering maintenance.

Such responses to PA creation could magnify local PA impact (while likely also creating non-local leakage) and that could significantly shift the optimal locations and types of new PAs. A natural step toward complete assessment of PAs' potential spillovers, then, is to empirically assess whether PAs do generate such potential responses. In this paper, I begin with an analysis of individual migration decisions within the Brazilian Amazon region and, controlling for other potential drivers, examine how these are affected by an intensification of the creation of PAs.

2.3 Models of Human Migration

A neoclassical economic perspective on migration is in Sjaasted (1962) and Todaro (1969)'s seminal studies. Migration is viewed as an income-augmenting investment, in which costs are incurred initially while the returns accrue over time. Any individual will compare the direct costs of migration with the discounted present value of income gains from each potential destination, searching for the maximum net gain from a set of potential migration gains. Under this view, younger people will obtain returns over a longer period, have larger gains, and be more mobile. Therefore, age helps to determine migration. The more educated are more likely to be migrants. Migrants also tend not to be from the poorest families, suggesting this is constrained by income.

Another literature addresses migrant selectivity by combining theories on individuals' migration decisions with human capital theory starting with Mincer (1974) and Becker (1975). Income at different locations is defined as a function of individuals' skills, which affect their productivity at each location. The human capital perspective implies that those who migrate have high differentials in discounted income (which could be expected income net of migration costs) between migrating and not migrating. Most recent microeconomic studies are based on this view, considering the income differential across origin versus potential destination locations as a key determinant of migration, while including other possible drivers such as characteristics of labor markets, transport networks and urbanization, plus other geographic characteristics that influence the location decisions of economic actors (see for instance Krugman 1990 and Fujita et al 1999).

New Economics of Labor Migration (NELM) sees the household as the unit of interest, with diverse preferences. Migration can provide capital and reduce risk by diversifying income. Family members are assumed to act collectively to maximize expected income and also to loosen the constraints associated with missing credit, insurance, and other markets (e.g. Taylor 1986).

Within the field of human geography, Lee (1966) has been highly influential. In his model, often referred to as the ‘push-pull’ model, the decision to migrate is determined by factors associated with the area of origin and area of destination, intervening obstacles such as distance, physical barriers, immigration laws, as well personal factors. Lee states that migration is selective with respect to the individual characteristics of migrants because people respond differently to ‘positive’ and ‘negative’ factors at different locations and have different abilities to cope with the intervening variables. This framework is more general than but not inconsistent with migration neoclassical models. Van Wey et al (2012) argue that in the push-pull model, one can think of ‘push factors’ as limited opportunities for employment in the origin. ‘Pull factors’ can be the opportunities in potential migration destinations, including urban employment, higher urban wages, available uncleared land, and amenities like health and education infrastructure.

Concerning PAs' migration impacts, Ogelthorpe et al (2007) say PAs can attract (pull) or repel (push) people. To ‘pull’, PAs provide benefits for local actors in the environs of the PA, for instance ecosystem services themselves or income if employment opportunities are available, e.g. in eco-tourism. PAs could then retain or attract human settlement. On the other hand, PAs may be seen as a ‘push’ force in that they constrain expansion or even continuation of economic activities, such as crop production or resource extraction, and/or deny access to traditional lands.

My empirical analysis of migration to follow is based directly upon the neoclassical view of migration. Individuals make choices about staying in a particular location, versus migrating to another of many potential other locations, based on which generates higher expected benefits. Applying that perspective, empirically I will explore how decisions to out-migrate from a given location are affected both by individuals' employment-relevant characteristics and characteristics of the locations themselves in order to provide a test of the impact of PA creation on migration.

3. Study Area, Data & Empirical Strategy

3.1 The Brazilian Amazon

The Brazilian Legal Amazon is a region of 521,742,300 hectares (about 5 million km2), which is close to 60% of Brazil's area. It contains the largest tropical forest in the world and one of the most important species hotspots, the Amazon Biome. About 44% of the Legal Amazon is protected, with 8% in Integral areas, 14% in Sustainable Use, and 22% in Indigenous Lands. Integral protection does not allow consumption, extraction or destruction of natural resources and restricts the presence of humans. Sustainable Use areas allow for the extraction of natural resources in attempting to make protection compatible with local socioeconomic development. In that vein, settlements are allowed in Sustainable Use PAs − and indeed in some cases that seems to be a prerequisite for creating this type of PA, focused on livelihoods (D'Antona et al 2013). The half of the PA network that is Indigenous Lands recognizes traditional communities' rights and is not officially designated as "conservation units" (Fearnside 2003). Most PAs were created after 1990 and, as noted above, on average PAs have had some impact in reducing deforestation.

According to the Brazilian Institute of Geography and Statistics (IBGE), by 2010 this region's population was near 24 million. Recent decades have seen urbanization plus population growth. At 20% for 2000 - 2010, the latter's rate is above the average for the rest of the country. Most of the population resides in urban areas and is distributed in 775 municipalities in the states of Acre, Amapá, Amazonas, Mato Grosso, Pará, Rondônia, Roraima, Tocantins, Maranhão and Goiás (only 0.8% of this state). D'Antona et al (2013) look at PAs created up to 2006 in the entire Brazilian Legal Amazon and estimate populations of 297,693 in Sustainable Use areas and 27,705 in Integral Protection areas, with 1,020,237 in areas around PAs. Overall, Amazon PAs were established in sites with relatively low population density and prior development (Figure 1).

3.2 Data

Brazil Demographic Census 2010

This dataset consists of 6,192,332 households and 20,625,472 individuals, equivalent to a 10.7% sample of all households. It is generated by a detailed questionnaire on household and individual characteristics, which considers migration. There are 2,903,042 person records for the Amazon, with municipality as the smallest unit, and variables include the municipalities where the person lived in 2005 and lived in 2010. I focus here on people who moved within the Amazon region. That is, currently I exclude those individuals who migrated out of the region or migrated into it.

I consider household heads older than 18 years of age in the analysis. I use information on the education level of each individual and created a dummy variable for completion of *ensino medio*, i.e., the last phase of basic education. There is information on the economic sector in which an individual works and I create a dummy variable for whether the person works in agricultural or extractive activities (versus in others sectors, such as manufacturing or services). Measures of income in 2010 exist but initially I have focused on prior conditions as determinants though the theories of migration discussed above certainly involve forward-looking expectations. Other relevant variables that I extracted from this census are the age and gender of individuals.

Subsamples of Microdata from Brazil Demographic Census 1991 and 2000

These subsamples were generated by IPUMS from the original records and were used to obtain some average characteristics of the municipalities from which the individuals were outmigrating. Only the 2000 Census was used for this purpose in this study. The 1991 dataset has 8.5 million observations (5.8% sample of the population), while the 2000 data has 10 million (6% sample). They provide similar information as is in the 2010 Census. The average income, unemployment rate and population density of each municipality in 2000 were calculated to use as determinants of migration. IPUMS also generates a variable called Minimum Comparable Area (MCA) which is a geographic unit that combines more recent municipalities in order to achieve consistency across time (and censuses). That is important for Brazil given significant changes in municipality boundaries across time, in particular subdivisions of municipalities into multiple municipalities. I have used these MCAs as the units of observations for analyses to be able to compare over time. Figure 2 shows the 288 MCAs in the sample.

Brazil Agricultural Census 2006

These data result from interviews with agricultural producers in 5,175,489 units of production throughout Brazil. Information is aggregated at municipality level and includes characteristics of the producers, characteristics of the establishments, employees, finances, value of production and resources used in production. I aggregate to the MCA units used for the Demographic Censuses. Two relevant variables are the number of hectares in agriculture by MCA, as well as the hectares in settlements supported by the National Institute of Colonization and Agrarian Reform (INCRA) to promote agricultural production by and provide technical assistance to families in those sites.

Geographic Data

Geographic characteristics affecting the profitability of the land are extracted from an 800,000 random pixel sample used in prior analyses of deforestation. I extracted MCA averages for soil quality, slope, vegetation and rain, as well as road density for different years. There are data on deforestation cover for 2000-04 and 2000-08, although in my initial analyses I did not use them. Finally, of course a necessary element of geographic or spatial data for my analyses are maps of the PAs with dates of PA creation. Those include Federal PAs, State PAs and Indigenous Lands, with the Federal and the State PAs identified as in either Integral protection or Sustainable Use.

3.3 Empirical Strategy

Migration often has been modeled as a discrete choice, a binary decision to move or to stay, in probit or logit models á(e.g. Emerson 1989, Finnie 2004, Chi and Voss 2005). Yet sometimes it is conceived as a choice among many locations that empirically is implemented using multinomial logit, probit or other maximum-likelihood techniques for estimating discrete-continuous models (e.g., Taylor and Mora 2005). Such studies are based upon a random-utility theoretical model, in which all of the migration decisions are taken to maximize welfare.

More recently, within the economic valuation of locational amenities, 'horizontal sorting' models apply a conditional logit framework to study households' choices across neighborhoods. Those choices are assumed to be responses to wealth and preferences for house characteristics, public goods, characteristics of neighbors, and commuting opportunities. This approach has been used to assess workers' choices across jobs, according to their qualifications and preferences for job attributes. Sorting models estimate structural parameters that characterize the heterogeneity of preferences (Kuminoff, Smith and Timmins 2012). Timmins (2007) develops an application of this framework for the entire Brazilian Amazon, one of few done for a developing country.

Given constraints on secondary data about individual migrations in the Brazilian Amazon, in particular on individuals' exact situations in their current locations plus all possible destinations, many studies of migration drivers focus on particular regions in the Amazon and rely on primary data instead (e.g., Caviglia-Harris et al. (2012), Parry et al. (2010), and VanWey et al. (2012)). Many lessons can be drawn from these detailed local case studies, yet I believe that these could be complemented with uses of secondary data for the entire region concerning individual moves across greater distances, even while controlling for individuals' specific economic opportunities. That can add to a bigger picture concerning migration's drivers and the development of regions.

To study PA impacts on migration, as in Timmins (2007), I use data for the entire region from the Brazilian Demographic Census at individual level. I study the drivers of the likelihood of household-head outmigration during 2005 and 2010 in a logit model with a binary dependent variable using individual characteristics and features of individuals' places of origin before 2005. Then I use multinomial (conditional) logit model to examine the individuals' MCA choices in that period, testing determinants from both origin and destination MCAs. I consider effects of:

- Individuals: age, education, gender, employment sector (agricultural/extractive or other)
- MCAs: Income per capita 2000, Population density 2000, Education HDI 2000
- MCAs: % in agriculture 2005, % in INCRA settlements 2005
- MCAs: dummies for above average % of area in Federal (Integral and Sustainable) PAs
- MCAs: dummies for above average % of area in State (Integral and Sustainable) PAs
- MCAs: dummies for above average % of area in Indigenous Lands
- States: dummies

In the multinomial logit model, I include dummies that proxy for moving costs across MCAs, based on distances between an individual's 2005 location and all potential destinations for 2010. One dummy is for zero distance, i.e., not changing MCA. The others are low, medium and high distance dummies.PA variables can represent total area within an MCA that was ever put into the given category of protection or a change (indeed both can be used in the same specification). I focus some on new PAs created during 2000 and 2004 that could generate new signals to others. Figure 2 shows that an important share of the total area in conservation was implemented then.

For the outmigration analysis, in order to partially address the endogeneity of PAs' locations, at least to the extent that is possible using the observable characteristics of locations, I employ propensity-score matching (Abadie and Imbens 2012) to find MCAs with low PA density that are otherwise similar to those with high PA density. They have similar relevant characteristics, e.g., similar population density, area in agriculture, education and state dummies, etc.. I then run the logit for matched samples.

4. Results

Our final sample contains 60,525 individuals, 31,548 migrants and 28,977 non migrants. Table 1 indicates less difference than one might suppose between the migrants and the non-migrants. Migrants have slightly higher levels of education and have achieved a higher income by 2010, i.e., after their recent migration, than non-migrants. More migrants are in urban centers by 2010. That is consistent with fewer migrants being employed in agriculture and extractive activities.

Table 2 presents average characteristics of the 288 MCAs in our sample. There are real differences across MCAs (and municipalities) in area, population density, and income per capita. Fractions of area in PA categories in 2005 (pre-migration) also vary significantly. Some MCAs have none of their area in PAs while others have more than half of it in some kind of protection.

Table 3 shows that using matching to preprocess the sample before running the analyses certainly helps to improve similarity between the treated and untreated MCAs. I define "treated" and "untreated" MCAs here in terms of a threshold for the density of protection. A treated MCA has a percentage above the average for MCAs, i.e., above 11%, for area that is under protection implemented during 2000-2004. Correspondingly, an untreated MCA has a fraction under 11%.

Given this definition, 38 MCAs from the sample are considered "treated". The controls are found by matching each treated MCA to an untreated MCA with the nearest propensity score, using nearest-neighbor matching (N=1). Table 3 shows matching achieved considerably better balances in covariates such as education and population density, which reduces some concerns. Most site characteristics have significant differences when comparing all of the treated with all the untreated MCAs. However, after matching, there remain none of the statistically significant differences. This includes when we move from just one untreated MCA for each treated MCA to two or three. That is helpful to have sufficient data for analyses, given the limited pool of MCAs.

Table 4 presents the results of the binary logit model for (non-) outmigration decisions. Looking within the matched sample, I find individual characteristics like education and gender to be positively and significantly linked with the likelihood of outmigration during this period. Employment in agriculture or resource extraction activities is associated with less outmigration, as is greater age, all of which is understandable. Concerning MCAs' characteristics, Federal PAs (both Integral Protection and Sustainable Use) have a positive significant effect on outmigration. Yet State PAs (both Integral Protection and Sustainable Use) show a negative significant impact. The evidence for Federal PAs is consistent with a 'halo' local forest spillover. This PA category in prior literature (Pfaff et al. 2014a) showed the strongest evidence of reducing deforestation in areas outside of but near PAs. Here, consistent with that result, and thus the idea that migration could be an underlying mechanism, Federal PAs are associated with more individuals moving.

Table 5 presents my conditional logit results using a 40% random sample of individuals (23,919). Each individual chooses among 288 alternative locations within the Brazilian Amazon. Using both origin and destination MCA characteristics, this analysis confirms the patterns in the outmigration analysis. Factors like income per capita, area in agriculture and INCRA settlements increase the likelihood of an individual choosing to move to or stay in an MCA. The migration distance dummies (high migration distance excluded from the regression) show that not moving, or moving to lower distances, can be much more attractive than moving to location farther away.

Federal PAs − Integral and Sustainable Use − have significant negative effects on the likelihood of choosing an MCA. State PAs have a significant positive effect, which could link with differences in enforcement or differences in the type of protection chosen. That is consistent with evidence on local PA spillovers, plus that between 2000 and 2004, the federal government actively discouraged deforestation, signalling a regime change to all, at least at the federal level.

5. Discussion

My results for impacts upon outmigration given establishment of PAs are consistent with prior results for local forest-conserving spillovers from some Amazon Federal PAs. Evidence from my analysis suggests that greater Federal PA density raises individuals' propensity to outmigrate. When I examine in a multinomial framework the choice of location during 2005-2010, greater Federal PA density more generally reduces the likelihood of choosing a location. That holds for both the Integral and the Sustainable Use PAs. It could be interpreted as evidence of migration as a mechanism underlying forest spillovers and, perhaps, even of shifts within development paths.

If pursuing an interpretation of migration as a mechanism to further reduce local clearing, Sustainable Use areas in particular should be studied further. As highlighted in Pfaff et al. 2014 for Acre State, this type of PA allows for some resource uses within PA boundaries and, consistent with the political economic implications of that approach, it is located closer to roads and markets (close enough for total impact, or blocking of pressure, to be above Integral PAs). Thus in these sites there is economic activity to be diverted. That generates avoided deforestation while posing a question: whose migration is influenced to permit a nearby 'halo' of lowered deforestation instead of local leakage? One possibility is that larger producers exit from the area. Sustainable Use PAs in particular might send a signal that distinguishes across producer groups: they permit some extraction within their borders but that tends to be for less capitalized actors; while their presence may dissuade larger producers from operating at their desired larger scales.

Thus, my results are at least suggestive of specific potentially important dynamics in the interaction of conservation policies and development processes. Such interactions will continue to be important to conservation's forest impacts as well as their distribution of economic impacts, and increasingly so if the scale of interventions rises with efforts at climate change mitigation.

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__Figure 1__

Location of PAs in the Brazilian Legal Amazon

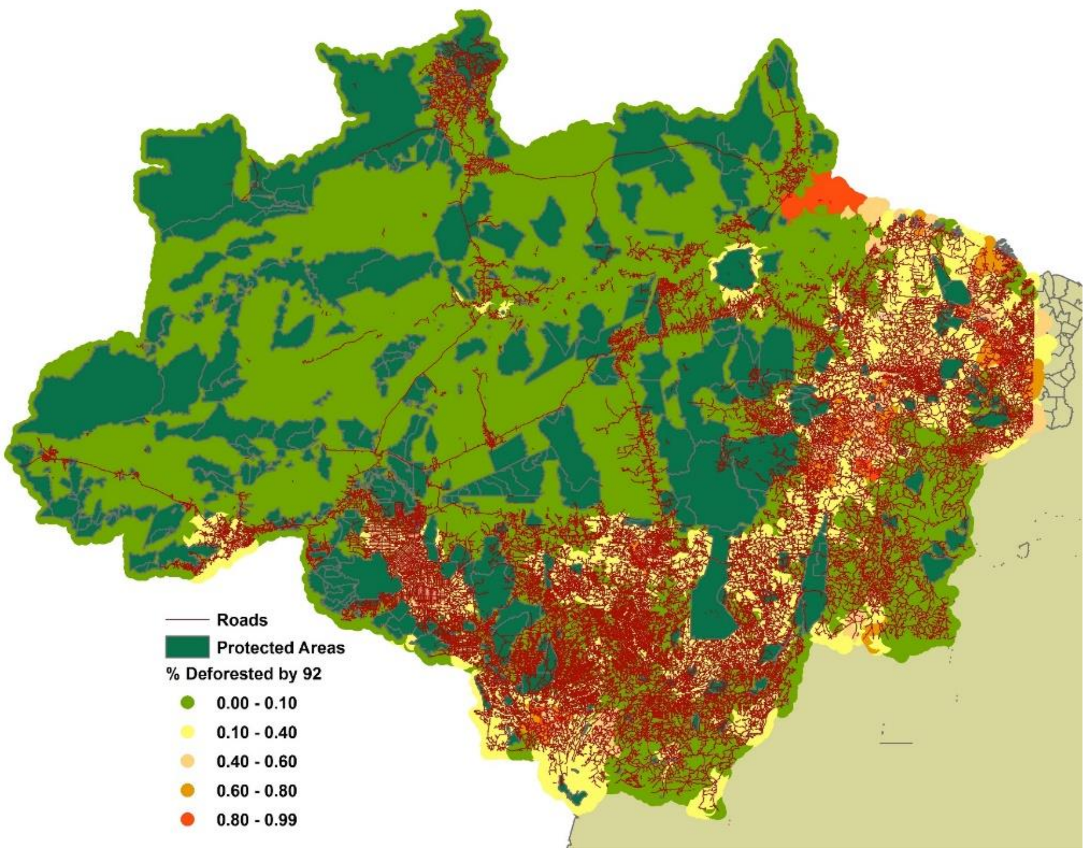

Figure 2

288 MCAS in sample (in green)

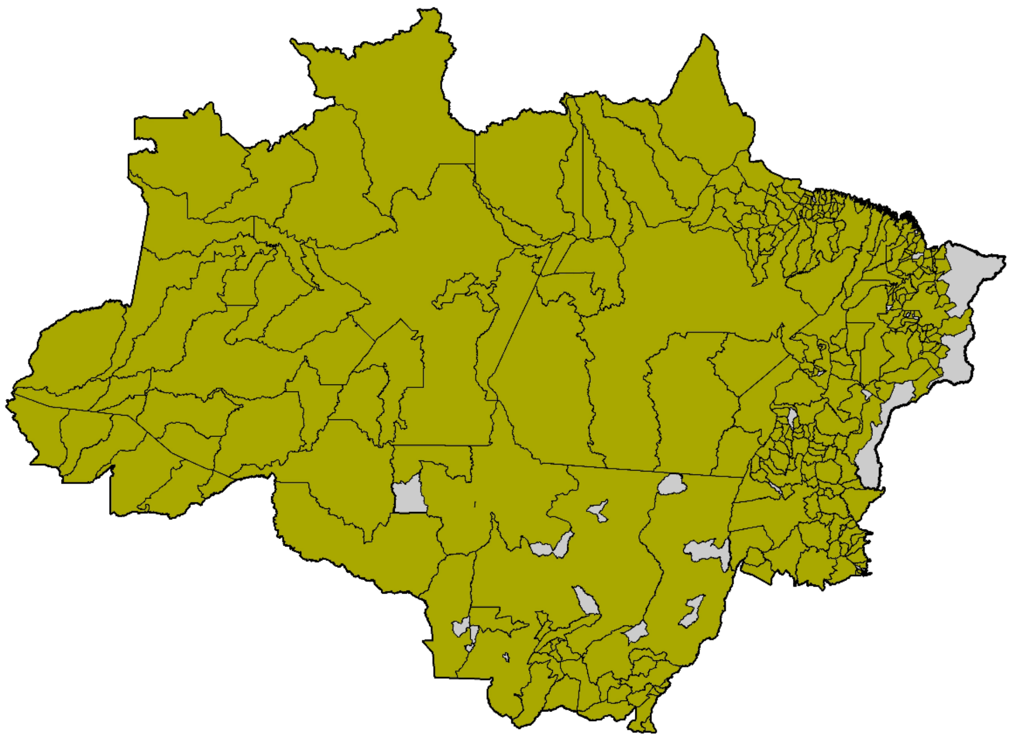

Figure 3

Cumulative area (1000 km^2) in Federal and State PAs

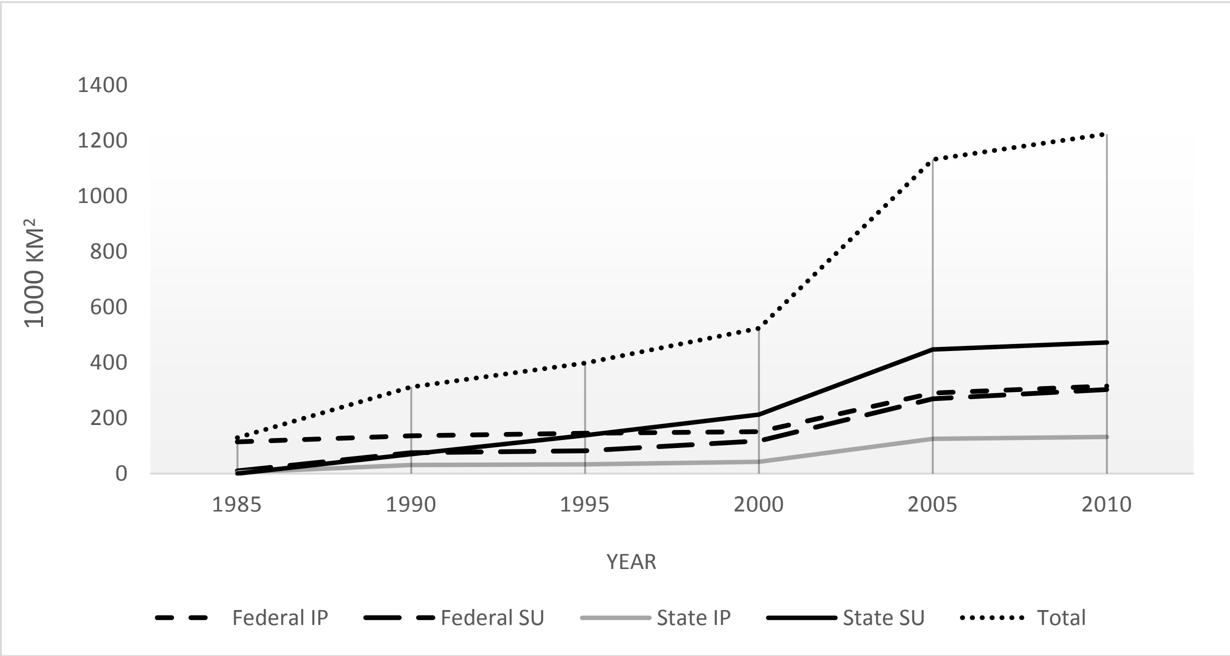

Table 1

Mean Individual Characteristics

	Migrants	Non-Migrants
Number of individuals	31,548	28,977
Percent with High Education	70%	68%
Average Individual income 2010	1298	1270
Percent working in Extractive or Agro sector	19%	22%
Percent living in Urban area by 2010	73%	71%
Percent of Male	69%	69%
Age	38	38

Table 2

MCA Characteristics

(288 MCAs)

Variable	Mean	Std. Dev.	Median	Min	Max
Area of MCA in ha	1,764,381	4,618,917	256,432.00	15,066	36,100,000
Population Density 2000	33	159	5.81	0.13	2127
Income per capita 2000	327	988	117	39	12,786
Education HDI	0.74	0.09	0.75	0.47	0.93
% in Federal Integral PAs 04	0.02	0.08	0.00	0.00	0.96
% in Federal Sustainable PAs 04	0.02	0.09	0.00	0.00	0.95
% in State Integral PAs 04	0.00	0.04	0.00	0.00	0.63
% in State Sustainable PAs 04	0.01	0.05	0.00	0.00	0.63
% in Indigenous Lands 04	0.05	0.13	0.00	0.00	0.84
% in Agriculture	0.41	0.28	0.39	0.00	1.00
% in INCRA settlement	0.00	0.02	0.00	0.00	0.24
Roads density	0.11	0.21	0.00	0.00	0.93
Slope (plain)	0.47	0.30	0.46	0.00	1.00
Soil Fertility Index	2.59	1.02	2.59	0.00	5.00
Vegetation (cerrado)	0.32	0.41	0.02	0.00	1.00

Table 3

Matching To Preprocess Data Improved Treated-Untreated Covariate Balance

Variable	**Sample**	**Treated**	**Controls**	**Difference**	**Std. Err.**
Matching balance N=1					
Variable	**Sample**	**Treated**	**Controls**	**Difference**	**Std. Err.**
Education HDI	Before Matching	0.70	0.74	-0.04***	0.02
	After Matching	0.70	0.69	0.01	0.03
Population Density	Before Matching	5.21	37.62	-32.41	27.90
	After Matching	5.21	7.15	-1.93	2.50
Area in Agriculture	Before Matching	0.18	0.45	-0.27***	0.05
	After Matching	0.18	0.28	-0.10*	0.06
Acre	Before Matching	0.08	0.01	0.07***	0.02
	After Matching	0.08	0.08	0.00	0.06
Mato Groso	Before Matching	0.08	0.02	0.06**	0.03
	After Matching	0.08	0.05	0.02	0.06
Matching balance N=2					
Variable	**Sample**	**Treated**	**Controls**	**Difference**	**Std. Err.**
Education HDI	Before Matching	0.70	0.74	-0.04***	0.02
	After Matching	0.70	0.71	-0.00	0.02
Population Density	Before Matching	5.21	37.62	-32.41	27.90
	After Matching	5.21	6.58	-1.37	2.16
Area in Agriculture	Before Matching	0.18	0.45	-0.27***	0.05
	After Matching	0.18	0.31	-0.13**	0.06
Acre	Before Matching	0.08	0.01	0.07***	0.02
	After Matching	0.08	0.05	0.03	0.06
Mato Groso	Before Matching	0.08	0.02	0.06**	0.03
	After Matching	0.08	0.05	0.03	0.06
Matching balance N=3					
Variable	**Sample**	**Treated**	**Controls**	**Difference**	**Std. Err.**
Education HDI	Before Matching	0.70	0.74	-0.04***	0.02
	After Matching	0.70	0.71	-0.00	0.02
Population Density	Before Matching	5.21	37.62	-32.41	27.90
	After Matching	5.21	6.88	-1.66	2.18
Area in Agriculture	Before Matching	0.18	0.45	-0.27***	0.05
	After Matching	0.18	0.33	-0.15***	0.05
Acre	Before Matching	0.08	0.01	0.07***	0.02
	After Matching	0.08	0.07	0.01	0.06
Mato Groso	Before Matching	0.08	0.02	0.06**	0.03
	After Matching	0.08	0.08	0.00	0.06

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$

Table 4

Logit model after PSM matching for 2005-2010 Outmigration[1]

	N=1		N=2		N=3	
Variable	**Coef.**	**Std. Err.**	**Coef.**	**Std. Err.**	**Coef.**	**Std. Err.**
Education	0.14***	0.03	0.14***	0.03	0.14***	0.03
Working in Agricultural Sector	-0.38***	0.03	-0.31***	0.04	-0.33***	0.03
Gender (male)	0.13***	0.03	0.12***	0.03	0.12***	0.03
Age	-0.00***	0.00	-0.00***	0.00	-0.00***	0.00
Low Population Density 2000	0.06***	0.01	0.07***	0.01	0.07***	0.01
Government settlement	-0.32***	0.10	-0.41***	0.08	-0.57***	0.09
Area in Agriculture	-0.09	0.20	-0.43***	0.14	-0.51**	0.13
Federal Integral PAs 0004 dummy	0.52***	0.06	0.52***	0.06	0.53***	0.06
Federal Sustainable PAs 0004 dummy	0.74***	0.14	0.80***	0.13	0.71***	0.12
State Integral PAs 0004 dummy	-0.17*	0.10	-0.38***	0.08	-0.36***	0.08
State Sustainable PAs 0004 dummy	-0.91***	0.11	-0.90***	0.10	-0.87***	0.10
Indigenous Lands 0004 dummy	-0.04	0.06	-0.01	0.06	0.00	0.05
Rondonia	-1.94***	0.08	-1.88***	0.07	-1.97***	0.07
Acre	-0.48***	0.14	-0.51***	0.11	-0.43***	0.11
Para	-0.21**	0.08	-0.25***	0.07	-0.37***	0.06
Tocantins	0.10	0.17	0.20**	0.11	0.21**	0.12
Maranhao	0.10	0.16	0.11	0.15	0.01	0.15
Mato Groso	-0.83***	0.13	-0.51***	0.09	-0.59***	0.09
Constant	0.43***	0.10	0.45***	0.10	0.53***	0.09
# individuals	26,714		30,115		31,846	

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$

1/ Comparing MCAs with over 11% in PAs created in 2000-04 to similar MCAs with under 11%

Table 5

Multinomial (Conditional) Logit for MCA Choice

Dependant variable: Choice of 288 MCAs	Coef.	Std. Err.
Income per capita 2000	0.22***	0.00
Area in Agriculture dummy	0.06**	0.02
Government Settlement dummy	0.75***	0.02
Migration Distance dummy (zero)	7.26***	0.06
Migration Distance dummy (low)	3.68***	0.06
Migration Distance dummy (medium)	1.21***	0.06
Federal Integral PAs 0004 dummy	-1.19***	0.11
Federal Sustainable PAs 0004 dummy	-0.49***	0.04
State Integral PAs 0004 dummy	0.99***	0.03
State Sustainable PAs 0004 dummy	1.55***	0.05
Indigenous Lands 0004 dummy	-0.44***	0.04
Rondonia	3.75***	0.14
Acre	1.13***	0.09
Roraima	3.73***	0.09
Para	0.48***	0.06
Amapa	3.37***	0.14
Tocantins	-0.02	0.07
Maranhao	-0.04	0.06
Mato Grosso	0.40***	0.07
# observations	23,919	

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$