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Deforestation, leakage and avoided deforestation policies: A spatial analysis

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ABSTRACT

This paper analyses the impact of several avoided deforestation policies within a patchy forested landscape. Central is the idea that one neighbour's deforestation actions may impact the returns to deforestation in nearby patches. We determine the impact of each policy in terms of avoided deforestation and leakage levels at the landscape scale through modelling and simulations. Avoided deforestation policies at a landscape level are respectively: two Payment for Environmental Services (PES) policies, one focused on deforestation hotspots, the second being equally available to all agents; a conservation area; and, an agglomeration bonus. Because our model accommodates spatial interactions in the absence of a deforestation policy, it is possible that a spatial policy can affect both within-intervention areas and outside-intervention spatial spillovers in terms of leakage across different landowners' forest patches. These two different elements of the total extent of displacement across the full landscape have not been considered before. Our contribution is twofold. In terms of methodology, we expand the concept of leakage in accounting for direct impacts to adjacent patches and spatial spillovers over the landscape, and we provide a measure of leakage in a dynamic manner for policy assessment. From our analytical model and simulations, we show that leakage is sensitive to the spatial distribution of forest patch types. The two PES policies are the most cost-effective policies regarding avoided deforestation. The agglomeration bonus policy is efficient at the expense of a higher cost, whilst the conservation area policy is efficient when patches with similar characteristics are gathered.

1. Introduction

High rates of deforestation and forest degradation continue to be of concern in many Low and Middle-Income Countries (LMICs), particularly so in the context of climate change and the role of forests in carbon sequestration. Where forests are owned and managed by private individuals, these private agents choose their optimal rate of deforestation based on the relative private costs and benefits of converting land. However, these forests may provide additional benefits that are not captured by the agent themselves, thus resulting in socially suboptimal levels of forest conversion. In the context

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of climate change, governments can attempt to influence private agents' decisions over how much of their forestland to convert to agriculture so as to align private and socially optimal choices. Governments might variously rely on regulation, the introduction of conservation areas or economic incentives such as Payments for Ecosystem Services (PES).

Increasingly it is recognised both in the literature and by policy makers that the impact and efficacy of such policies depend not just on the specific details of the intervention, but also on spatial interactions across the forest landscape, and in particular, on the extent of "leakage". In the context of greenhouse-gas emissions and the REDD+ (Reduced Emissions from Deforestation and Forest Degradation) mechanism, leakage is the term given to a "net increase of greenhouse-gas emissions in an area outside the project resulting from the [project] activity" (Schwarze et al., 2002), and occurs "whenever the spatial scale of intervention is inferior to the full scale of the targeted problem" (Wunder, 2008). Leakage is recognised in the Bali Action Plan – COP 13 as a "displacement of emissions" whereby a reduction in greenhouse-gas emissions in one area (or activity) leads to higher emissions in another area (or activity). Such leakage can occur through so-called "activity-shifting leakage" whereby individuals responsible for deforesting and forest degradation shift some or all of their activity from the more protected REDD forest to a less protected location (Aukland et al., 2003; van Oosterzee et al., 2012); or "market or partial/general equilibrium leakage" (Gan and McCarl, 2007; Meyfroidt and Lambin, 2009; Rosendahl and Strand, 2011; Carbone, 2013) in which the leakage is transmitted through markets, reflected in changes in price for forest resources.[1] Addressing leakage has been widely recognised as a major challenge when designing climate mitigation policies that incorporate a REDD+ scheme (Wunder, 2008; Albers and Robinson, 2013). Thus, whilst a particular initiative might be demonstrated to be successful in terms of reducing deforestation within the project boundaries, if deforestation is displaced outside the project area, then the actual effectiveness of the policy will be lowered.

Only a small number of papers in the literature have developed explicitly spatial models of leakage towards deforestation and public policies. Among them, Murray et al. (2004) explore the impact of leakage from a reserve to a forested area outside a reserve through a "price-induced supply response". The presence of a reserve creates an excess demand for timber relative to the reduced supply, the price rises, and the excess demand is met from outside the reserve. Gan and McCarl (2007) develop a theoretical model of transnational leakage. Again, the mechanism is through prices, and the extent of leakage is determined by the price elasticities of supply and demand for forest products. Robinson et al. (2011) demonstrate theoretically that reduced deforestation due to the implementation of a protected area is likely to increase nearby deforestation when labour and product markets are not functioning efficiently, but have no local impact when markets are efficient. Delacote and Angelsen (2015) propose an understanding of the pattern of shifting activities that may create leakage between agricultural expansion and forest products harvesting: when land and labour are complements in the net return function of the households, a policy aiming at reducing deforestation may indirectly increase forest degradation.

In addition to these contributions, there is a growing body of literature that aims at evaluating policy effectiveness whilst combining modeling and empirical strategy in taking into account net effects of leakage (Wear and Murray, 2004; Murray, 2008; Honey-Roses et al., 2011; Miteva et al., 2012; Alix-Garcia et al., 2012; Baylis et al., 2013; Sims, 2014). In particular, Alix-Garcia et al. (2012) propose an evaluation of Mexico's national payments for hydrological services program *Pago por Servicios Ambientales-Hidrológico* (PSAH) under both types of slippage. They show that this PES program had relatively moderate impacts on deforestation between 2003 and 2006. They provide evidence for both types of leakage, of which the substitution slippage effect reduced avoided deforestation by about 4%. Sims (2014) studies the impacts of wildlife sanctuaries and national parks in North and Northeast Thailand that are strictly protected areas. She develops and applies an approach for retrospective empirical evaluation of policy impacts on habitat fragmentation, whilst dividing regional landscapes into "micro-landscapes" to assess whether and to what extent protected areas prevented forest loss and fragmentation. She shows that forest cover increased by an estimated 19%, whereas average forest patch size and maximum forest patch size increased respectively by 25% and by 21%, compared to a counterfactual scenario of no protection.

Yet even without explicit policy interventions, there are likely to be spatial interactions due to deforestation choices in one area influencing those in other areas, that is, non-policy-induced leakage. Indeed, Robalino and Pfaff (2012) suggest that "interactions should be considered in predicting deforestation over space and time (. . .) when designing spatial incentive schemes." They find empirically in Costa Rica that for a given location, neighbouring deforestation raises the probability of deforestation, an example of negative leakage, or complementarity in clearing (the opposite finding would be an example of classic leakage, or substitutability in clearing). This observation raises the possibility of strategic substitutability and strategic complementarity, either in clearing or in conservation (Robalino and Pfaff, 2012).[2] These observations suggest that there is a need to analyse situations of strategic interaction before any governmental interventions, thus recognizing non-policy induced leakage, in addition to policy-induced leakage.[3]

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[1] Leakage has similarly been referred to with respect to conservation policies. For example, evaluation of the U.S. Conservation Reserve Program (CRP) (Wu, 2000; Wu et al., 2001; Roberts and Bucholtz, 2005; Lichtenberg and Smith-Ramirez, 2011), highlighted substitution slippage (activity-shifting-based leakage) and output-price slippage (market-based leakage) as reducing the policy effectiveness.

[2] Amin et al. (2014) and Sauquet et al. (2014) present cases of spatial strategic interactions between municipalities in Brazil, which can be considered as leakage in a situation of strategic substitutability.

[3] In connection with these strategic interactions and the impact of policy implementation, one has to observe the sign of leakage. Baylis et al. (2013) (following Armsworth et al. (2006) or Oliveira et al. (2007)) states that "*more commonly, leakage is positive resulting from increased pressure to deforest in adjacent lands, relocation of indigenous communities from protected areas to adjacent areas or by preemptive clearing of forest by landowners around newly created restricted-use areas*".