ELSEVIER
www.elsevier.com/locate/worlddev

World Development Vol. xx, pp. xxx–xxx, 2016

http://dx.doi.org/10.1016/j.worlddev.2016.11.012

What has Driven Deforestation in Developing Countries Since the 2000s? Evidence from New Remote-Sensing Data

ANTOINE LEBLOIS [a], OLIVIER DAMETTE [b] and JULIEN WOLFERSBERGER [c,*]

[a] *INRA, Nancy, France*

[b] *BETA-CNRS UMR7522, Université de Lorraine, Nancy, France and Team CAC (Cliometrics and Complexity), IXXI Complexe Systems Institute Lyon, France*

[c] *INRA, Paris, France*

Summary. — Using newly-released and globally available high-resolution remote sensing data on forest loss, we update the assessment of the cross-country determinants of deforestation in developing countries.

We validate most of the major determinants found in the previous literature, generally based on earlier time-periods, except for the role of institutional quality. Agricultural trade, hitherto relatively neglected, is found to be one of the main factors causing deforestation. Focusing on the effect of international trade, we show that countries with different levels of relative forest cover react differently to a shock in agricultural exports' value. We also emphasize that taking countries' development into account may be critical in assessing global deforestation trends. The impact of trade is high in countries still endowed with a large proportion of forest cover while it is lower in countries with smaller remaining forest cover.

We finally estimate, through a simple calibration exercise, the requirements for a cost-effective REDD+ policy for compensating trade losses in an open economy exporting agricultural commodities and endowed with tropical forests. We conclude that, in a world with increasing global demand, it might be costly to compensate totally and thus to offer the right incentives for developing countries to limit deforestation.

Key words — deforestation, development, international trade

1. INTRODUCTION

Deforestation in the tropics remains an important environmental issue in the context of global climate change and biodiversity losses. For example, the International Panel for Climate Change IPCC (2014) states that "the Agriculture, Forests and Other Land Uses" (AFOLU) sector currently represents a quarter of world greenhouse gas emissions.

Economists have been studying the drivers of deforestation for a long time, and at different scales Angelsen and Kaimowitz (1999). Analyzing its underlying causes has highlighted economic development, population pressure and institutions as important determinants of forest loss in the tropics. [1] However, as we explain in Section 2(b), only a few studies have looked at determinants of deforestation since the 2000s.

The purpose of our paper is to provide an update of the recently-observed determinants of deforestation in tropical countries using a new data-set based on time-series analysis of satellite images, offering a unique level of precision concerning forest losses (Hansen *et al.*, 2013).

The contribution of this paper lies in testing competing determinants of recent deforestation and in the use of new data of a unique quality. To the best of our knowledge, it is the first study that has used this dataset in order to statistically assess the underlying causes of deforestation in a cross-country panel [2] framework. Although some studies at the sub-national level were already based on such data (Alesina, Gennaioli, & Lovo, 2014; Burgess, Hansen, Olken, Potapov, & Sieber, 2012; Blankespoor, Dasgupta, & Wheeler, 2014; Lubowski *et al.*, 2014; Busch *et al.*, 2015), they have still never been used in a cross-country panel framework. Indeed, so far, macroeconomic empirical analysis has been based on the widely criticized data provided by the FAO, [3] and focused on periods prior to the 2000s.

Different data sources lead to different assessments of global forest resources. According to the last Forest Resource Assessment from FAO (2015), deforestation has been slowing down: from an annual average rate of 0.18% in the early 1900s to 0.08% during the period 2010–15. This decreasing trend is at odds with another study, Kim *et al.* (2015), showing that deforestation increased by 62% in the 2000s relatively to the previous decade, using very similar data to the Hansen *et al.* (2013) dataset, also uniquely based on land cover imagery processing. Moreover, as explained in Li *et al.* (2016), a different canopy fraction is adopted in the forest definition in the two methodologies: over 10% in the FAO assessment against a threshold of 25% in Hansen *et al.* (2013).

We conducted our panel analysis for the period 2001–10, using the usual explanatory variables present in the literature. Our analysis suggests that (i) usual drivers of deforestation (population density, economic development and agricultural activity) tend to explain the dynamics of deforestation at the

* Comments from the editor, 2 anonymous referees and participants to the 2015 EAERE conference in Helsinki, in particular those from Prof. Dr. Emma Aisbett were helpful. We also thank Ruben Lubowski for his expertise and for helping with the interpretation of the 1 arc minute forest land cover cells. All mistakes are ours. Olivier Damette would like to acknowledge the founding of *Université de Lorraine* and *Region Lorraine*. The UMR LEF is supported by a grant overseen by the French National Research Agency (ANR) as part of the "Investissements d'Avenir" program (ANR-11-LABX-0002–01, Lab of Excellence ARBRE).This article was written when Olivier Damette was on leave at the UMR LEF at INRA. Final revision accepted: November 21, 2016.

Please cite this article in press as: Leblois, A. *et al.* What has Driven Deforestation in Developing Countries Since the 2000s? Evidence from New Remote-Sensing Data, *World Development* (2016), http://dx.doi.org/10.1016/j.worlddev.2016.11.012

national level in the 2000s as was the case during previous decades. However, we do not find evidence that institutional quality (measured by governance and freedom indices) influence deforestation. More importantly, we found evidence that (ii) trade in forestry and agricultural commodities, a factor which has been quite neglected in previous literature, is an important factor in forest clearance and that (iii) the impact of trade is predominant in countries still endowed with a large proportion of forest cover.

The paper is organized as follows. The second section presents a literature review of the determinants of deforestation. Section 3 describes the data and the recent trends in forest land cover and losses at the national level. Section 4 presents the results of the analysis of the standard determinants of deforestation and Section 5 investigates the effect of trade. Section 6 concludes.

2. DETERMINANTS OF DEFORESTATION: A REVIEW

(a) *Trade as one of the main channels identified in recent studies*

Recent studies have highlighted trade as a potential driver of deforestation. Faria and Almeida (2016) show empirical evidence that during 2000–07, when Brazilian municipalities of the *Amazonia Legal* opened to international trade, deforestation increased. This is also the case of studies emphasizing the role of industrial production oriented toward international trade. DeFries, Rudel, Uriarte, and Hansen (2010) show the same relationship at the national level for the period 2000–05, arguing that policies should focus on reducing deforestation that is carried out for industrial-scale, export-oriented agricultural production. In the same vein, Hosonuma *et al.* (2012) shows that commercial agriculture is the first determinant, followed by subsistence agriculture. Finally, Gaveau *et al.* (2016) examined the effect of industrial plantation in Borneo since the 1970s. These authors find that it has been the main cause of deforestation of old-growth forests in the Malaysian part, and to a lesser extent in the Indonesian part too. However, the limited availability of aggregated data at the national level about the type of agriculture (subsistence *vs.* commercial) prevents the use of robust quantitative methods.

Schmitz *et al.* (2015) show that further liberalization would lead to an expansion of deforestation in Amazonia due to the comparative advantages of agriculture in South America. Globally, they estimate, using a spatially explicit economic land-use model coupled to a biophysical vegetation model, that an additional area of between 30 and 60 million ha (5–10%) of tropical rainforests would be cleared, leading to 20–40 Gt of additional CO_2 emissions by 2050.

Facing such pressure, conservation is put forward as one of the main solutions for a policy-oriented response (Schmitz *et al.*, 2015). Lavelle *et al.* (2016) investigate the sustainability of deforested land in the Brazilian Amazon using socioeconomic and environmental data. While sustainability, as defined by their own index, decreases over time, they find that agroforestry practices can be used to achieve environmental and social goals in the region.

The effectiveness of protected areas in preventing deforestation in the tropics has already been thoroughly examined. For instance, Haruna, Pfaff, van den Ende, and Joppa (2014) discuss the importance of forward-looking plans when implementing those protected areas in Panama, Robalino, Sandoval, Barton, Chacon, and Pfaff (2015) study the optimal spatial distribution of these policies in Costa Rica. Finally, this subject has been looked at by two other research teams (Blankespoor *et al.*, 2014; Maher *et al.*, 2013) working with the same dataset that we use in this article. However, Pfaff, Robalino, Herrera, and Sandoval (2015) find that protected areas tend to be located on land facing less pressure which would reduce the efficiency of such policies. This is consistent with Ferretti-Gallon and Busch (2014) and Heino *et al.* (2015) results showing limited impact of protected areas on deforestation at the national level and high heterogeneity across countries.

Amin *et al.* (2015) nevertheless found that, if leakage reduces the amplitudes of reduction in deforestation, it does not annihilate it. Moreover Nolte, Agrawal, Silvius, and Soares-Filho (2013) has found that lands under sustainable use, strict protection as well as indigenous land, efficiently reduced deforestation in the 2000s, in an empirical estimation on 264 Amazonian municipalities. Barber, Cochrane, Souza, and Laurance (2014) found it is true even when properly controlling for access to transportation (different types of roads and navigable rivers).

This result validates the ones of Nelson and Chomitz (2009), Nelson and Chomitz (2011) who showed that strict protected areas were more efficient in reducing deforestation than multi-use protected areas, although endogeneity may exist in the localization of multi-use areas, generally located in zone of higher deforestation pressure. However spatial leakage is not controlled in those analysis. And such result does not seem very robust since Nelson and Chomitz (2011), Ferraro *et al.* (2013) show the very high heterogeneity in the positive relation between strictness of protection and performance in terms of deforestation reduction within and across countries and continents. Pfaff, Robalino, Lima, Sandoval, and Herrera (2014) also investigated the efficiency of governance in managing protected areas (PAs) in one specific state of the Brazilian Amazon. They found that the beneficial effect of PAs was actually driven by location: PAs with a strict-blocking governance were assigned to areas with low pressure (weak development and poor population density), i.e., in areas where deforestation was less likely to take place even in the absence of public policies. For this reason, they claim that sustainable use areas helped reducing deforestation more significantly. To do that, the authors used spatial data only available at the state-scale. Moreover, Rasolofoson, Ferraro, Jenkins, and Jones (2015) has showed that community forests are not always reducing deforestation, they are efficient only if they do not allow commercial use of the forest. As well, Bottazzi and Dao (2013) studied the impact of political processes on forest harvesting in the Bolivian Amazon. Authors also took into account some spatial impacts only visible at the state level. They found that collective property rights were attributed to remote areas with little or no pressure on forests, and that this was explaining the fact that this regime of land rights exhibited less deforestation.

(b) *Statistical determinants: a review of cross-country panel studies*

In this section we review the determinants of deforestation found in the economic literature more systematically. Geist and Lambin (2002) distinguish biophysical, economic or technological, demographic or institutional and cultural factors leading to deforestation. We will focus on economic, demographic and institutional factors. Many of them are found in a recent meta-analysis (Ferretti-Gallon & Busch, 2014) including microeconometric studies and thus incorporating additional variables such as road network density, commodity prices, protected areas and payment for ecosystem services among others.

Please cite this article in press as: Leblois, A. *et al.* What has Driven Deforestation in Developing Countries Since the 2000s? Evidence from New Remote-Sensing Data, *World Development* (2016), http://dx.doi.org/10.1016/j.worlddev.2016.11.012