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Analysis

An empirical analysis of forest transition and land-use change in developing countries

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ABSTRACT

Deforestation is a major environmental issue in developing countries, and agricultural land expansion is its main cause. The objective of this paper is twofold:(1) to identify the macroeconomic determinants of ending deforestation; and (2) to explain cumulative deforestation and other land uses. To do this, we first study the probability of a turning point for deforestation (i.e., the switch from decreasing to expanding forest areas), based on the Forest Transition hypothesis. Second, we adapt a land-use model to explain the trade-off between forest and agriculture during development. To take the link between both phenomena into account, we estimate a dynamic panel seemingly unrelated regression (SUR) model along with a switching regression model, applied to a dataset of 57 developing countries observed over four time periods. The estimation results reveal that economic development and institutions play a significant role in long-term deforestation. Our results also suggest that after the first development stage, agriculture and forest are not always competing land uses. These results provide new insights into public policies such as REDD+.

1. Introduction

Deforestation in tropical countries is responsible for CO_2 emissions, biodiversity loss, desertification, flooding and other environmental damages. Until now, the wide empirical macroeconomic studies on deforestation (using panel data on deforestation at a country level, provided by FAO) have given useful results concerning the factors that account for periodic deforestation rates (annual or over a five-year period). First, the literature questioned the impact of economic development on deforestation, by investigating the existence of an Environmental Kuznets Curve for deforestation (most recently Culas (2012); Busa (2013); Chiu (2012)). Those studies bring very contrasted results, as shown in the meta-analysis by Choumert et al. (2013). Second, institutional factors such as corruption, land tenure quality and more broadly the quality of countries governance were proven to be an important macroeconomic factor of deforestation (Barbier and Burgess, 2001; Bhattarai and Hammig, 2001; Culas, 2007; Galinato and Galinato, 2013). Other studies found evidence that other macroeconomic factors are correlated to deforestation. They encompass the role of real exchange rates (Arcand et al., 2008), agricultural activity (Barbier, 2004), access to capital, public policies (Benhin and Barbier, 2004; Combes-Motel et al., 2009), population (Cropper and Griffiths, 1994) or timber harvesting (Damette and Delacote, 2011). Heilmayr, (2014) investigates the impact of plantations on natural forests: plantation expansion is negatively correlated to natural forests dedicated to forest product extraction, and positively related to unharvested natural forests and the associated generation of ecosystem services. This result suggests that plantation and natural forests are complements in terms of ecosystem services provision and substitutes in terms of wood production. To obtain these findings, most studies regressed the deforestation rates of developing countries on a set of explanatory variables over a given period. Yet, a few papers contributed to the literature by implementing particular econometric techniques. Scrieciu, (2007) underlines the importance of correctly treating autocorrelation to obtain efficient estimators, Nguyen-Van and Azomahou, (2007) implemented non-parametric estimations, while Damette and Delacote (2012) apply quantile analysis.

Yet, although it is important and useful to have a good understanding of the factors of deforestation at yearly rates or over few years period, it is also crucial to have a better knowledge of the explaining factors of the end of deforestation in a given country. Indeed, this allows considering deforestation from a longer perspective, in the sense that when deforestation ends, cumulative deforestation and remaining forest cover can be assessed. For this purpose, we refer to the Forest Transition (FT) hypothesis introduced by Mather (1992), described as "*the change from decreasing to expanding forest areas that has taken place in many developed countries*". It describes the entire evolution of

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the forest cover in a country as it develops, according to three major phases: deforestation, stagnation and reforestation. The point at which the forest cover reaches its minimum and sustainably stops decreasing is called the turning point. This point constitutes the core of our analysis since it makes it possible to consider the cumulative deforestation of a nation all along its development path. It also provides structural information about the entire deforestation stage since the forest cover is no longer decreasing. Other empirical papers relying on the forest transition hypothesis show evidence that yearly deforestation rates are correlated to the remaining forest cover (Ewers, 2006), while Köthke et al. (2013) show that the forest transition model can explain the global patterns of deforestation for a set of 140 countries.

In developing countries, land-use competition occurs mainly between agriculture and forest, and agricultural land expansion represents the major direct cause of deforestation.[1] Gibbs et al. (2010) reported that between 1980 and 2000, across the tropics, "*more than 55% of new agricultural land came at the expense of intact forests, and another 28% came from disturbed forests*". Hence, the cumulative nature of deforestation can only be understood within a land-use approach.

Our paper contributes to the literature on both thematic and methodological sides. In terms of thematic, our contribution is twofold: first, in contrast to previous works, we focus on the end of the process, the moment when deforestation ends in a given economy, for the purpose of identifying the macroeconomic factors that promote the sustainable switch from deforestation to reforestation in a developing country; second, we investigate factors explaining the land use and the remaining forest cover once this ending point of deforestation has been achieved, which gives a valuable indication of the remaining forest cover that the country has been able to preserve. Our results could potentially contribute to the design of public policies such as REDD+, which aim at shortening transitions in low income countries still undergoing deforestation. Several implications may then be expected in terms of carbon sequestration or biodiversity conservation. Indeed, our analysis provides recommendations for public policies in order to accelerate the reforestation phase, thus increasing carbon sequestration by forests, in particular. Some important economies such as China and India are currently experiencing a turning point. Accelerating their phase of reforestation could thus greatly benefit global climate.

The methodological contribution of this paper concerns the fact that the occurrence of a turning point and the level of deforestation are two different yet correlated issues. We may in fact expect the end of deforestation to be related to a lower level of forest cover. Land-use determinants are likely to be different in both regimes, i.e., depending on whether a country is at the turning point or still experiencing deforestation. Moreover, several factors simultaneously explain the occurrence of a turning point and the distribution of land uses. Some factors can be observed, whereas for some others, direct observation is more difficult (when related to public (country) preferences, for example). We used a dynamic switching seemingly unrelated regression (SUR) model for panel data, which consists of two steps: (1) estimating a probit model that explains the occurrence of a turning point; and (2) estimating a system of land-use shares for two different regimes: $FT = 1$ when the developing country has experienced a turning point for deforestation, and $FT = 0$ when the developing country is still undergoing deforestation.

The next section presents the FT hypothesis and some empirical observations. The third section details the conceptual models of turning point and land allocation, and lays out the econometric procedure. Data are described in Section 4. Section 5 presents the results, and Section 6 is devoted to a discussion on implications for public policies.

[1] Expanding agriculture may also cause indirect land-use changes. These occur when agricultural activities shifted from one region, leading to the expansion of the same land use in another region (Andrade de Sá et al., 2013).

2. The Forest Transition Hypothesis

2.1. Background

During the early development phase, the main land-use trade-off pits agriculture and forest against each other. In response to economic incentives, land use choices are made at the microeconomic scale. When aggregated, they form a macroeconomic trend that can be viewed as the land use/cover change (LUCC) of a given country or region. For several decades now, researchers have taken an increasing interest in the LUCC in order to better predict the impact of local actions on global climate change (Lambin et al., 2003). The FT hypothesis is a component of the LUCC framework since it allows a better understanding of the evolution of the forest area of a country and, as a result, the consequences in terms of climate or ecology. Following the FT hypothesis, the forest cover varies under different phases: deforestation, stagnation and reforestation (see Fig. 1).

The major phase of deforestation is composed of two stages. First, new accesses to forests are created through roads (Li et al., 2014), both for state control and rent access (mining, logging, etc.). This boosts agricultural rents by providing new markets that lead to a population shift towards the area. The global rate of forest losses remains low, considered as the pre-development phase. Second, the growth of the local population implies a strong demand for food and space and ensures the supply of labor at low wages. This population effect is combined with the development of processing activities such as dairies or slaughterhouses. Agricultural rents are relatively high and production expands. The clearing process is reinforced (Angelsen, 2007) and the deforestation rate is high. This is the major phase of deforestation that provides income and capital, and makes it possible to satisfy food and energy needs.

Following the deforestation phase, a phase of stagnation occurs as agricultural rents decrease and forest rents increase, determining the turning point for deforestation. This corresponds to a reversal in the deforestation rate: the net variation of the forest cover sustainably turns from negative to positive or null. Grainger (1995) points out that the period of stagnation may last decades or even centuries, like in the case of England. Different paths based on empirical observations explain the occurrence of a turning point.

The economic development path was formalized by Rudel et al. (2005). Once a certain level of income per capita and of capital stock is reached, the country is able to switch from an agriculture-based economy to an industry-based economy. Farmers leave their lands for urban jobs with higher wages. Agricultural production becomes more intensive and some previously abandoned lands revert to forest. The development path is consistent with the Environmental Kuznets Curve (EKC) hypothesis, where deforestation and income are related by an inverted U-shaped relationship. Several empirical studies on deforestation have tested this relationship, finding contradictory results (Choumert et al., 2013). However, the development path (1) is specifically related to forests, whereas the EKC concerns any type of

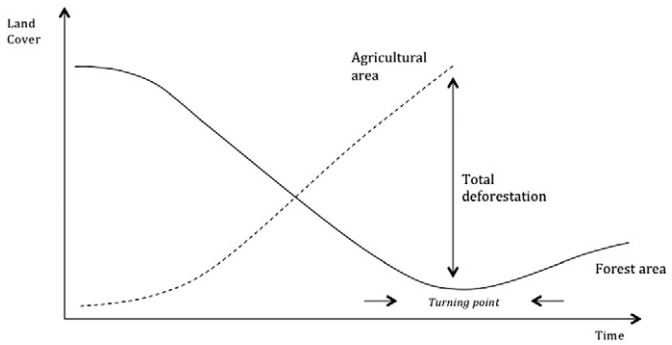

Fig. 1. Land use change in the forest transition framework.