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WORKING PAPER

PUBLIC SPENDING, CREDIT AND NATURAL CAPITAL: DOES ACCESS TO CAPITAL FOSTER DEFORESTATION

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Improving access to man-made capital through domestic credit and public spending is a step towards development. Developing countries rely also on natural capital, which may generate possible conflicts between environment and development targets. Taking the case of land-use and deforestation, this paper revisits the links between man-made and natural capital. Relying on a model of income maximization, we theoretically assess how better access to man-made capital through public spending and credit, influences forest cover loss. Econometric investigations, over the period 2001-2012, show that forest cover loss is positively influenced by credit and public spending. A better access to capital is thus detrimental to the forest. This can be interpreted as a Tinbergen rule: the development objective of facilitating access to man-made capital cannot be tackled without facing the objective of environmental protection.

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1 Introduction

Natural capital constitutes a far greater share of the wealth of developing countries than that of man-made capital. Natural capital thus represents a pivotal element in sustaining the development and welfare of developing countries (the World Bank, 2005; Ruta and Hamilton, 2007). An iconic form of natural capital is the one of forested land, of which conversion into crop and pasture land and timber harvesting can be seen as the use of natural capital in an attempt toward poverty alleviation (Wunder, 2001; Celentano *et al.*, 2012) and economic development by agents lacking other forms of capital (Azqueta and Sotelsek, 2007; Barbier, 2011). However, relying heavily on natural capital in the early stages of development can bring serious environmental concerns. Land conversion and deforestation have global and local environmental impacts, such as climate change, biodiversity loss and accelerated erosion of local forest ecosystem services.

At the same time, improving access to man-made forms of capital is an important development objective. The Sustainable Development Goals illustrate how crucial is the investment in essential infrastructures for economic development (Goal 9) or in human capital and the better management of natural resources (Goal 15) like the forests. A crucial question to investigate is then the relationship between natural capital and man-made capital: how does better access to man-made capital influences the reliance on natural capital?

This relationship has been extensively investigated within the weak vs. strong sustainability debate, which dates back to the 1970s.[1] The weak sustainability approach, which is rooted in mainstream economic analysis, asserts that the different forms of capital are substitutes: natural capital depletion can contribute to (and be replaced by) the accumulation of man-made capital. Optimal growth models have been extended where the conditions of technical progress and substitution between natural and man-made capital are analyzed (Dasgupta and Heal, 1974; Solow, 1974; Krautkraemer, 2005; Bretschger and Smulders, 2012). They suggest that substitution between natural and man-made capital can create the conditions of boundless economic development, even in

[1] 1 See, for example, Neumayer (2013) for an in-depth presentation of this debate.

a world with finite natural capital. van Geldrop and Withagen (2000) show that broadly defined natural capital converges to a steady state provided there exists a sector that allows investments in natural capital.

This weak view of sustainability has been challenged by proponents of the strong sustainability paradigm. They put emphasis on the specific characteristics of natural capital, which lead them to argue in favor of maintaining a minimum amount of the different types of natural capital (Daly and Townsend, 1993; Daly, 1994, 1997; Ayres, van den Bergh and Gowdy, 1998). The main premise of this argument is that natural capital differs from other forms of capital in many different ways, which creates complementarity between man-made and natural capital (Cleveland and Ruth, 1997; Stern, 1997; England, 2000). For instance, natural capital's depreciation is an irreversible phenomenon, degraded natural assets are often considered as irreplaceable and lastly are subject to abrupt collapses and irreversible changes quoted as tipping points (Dasgupta, 2007). Therefore, natural capital may become a constraint on development and thus be the key factor generating environmental crises (Scott Taylor, 2009). The authors of the updated Meadows Report (Meadows, Randers, and Meadows, 2005), or more recently Diamond (2013), illustrate such environmental crises, giving examples of unsustainable and collapsing societies that have relied too heavily on natural capital depletion.

Facilitating access to credit and the use of government expenditure are ways to increase the stock of man-made capital. Our research question is thus more precisely: does increased access to man-made capital through the provision of domestic credit and public expenditures tend to increase or to relax the use of natural capital? Our intuition is that diverse forms of man-made capital may not have homogenous impacts on development and on natural capital use.

Some papers have investigated the impact of access to credit on environmental issues. Antle, Stoorvogel, and Valdivia (2006) argue that credit constrained agents may underinvest in natural resource conservation. Shahbaz *et al.* (2013) find that financial development reduces CO_2 emissions. Several authors argue that deforestation may be capital-driven (Rudel and Roper, 1997; Geist and Lambin, 2001). For instance, credit allows the financing of investments in infrastructure that boosts deforestation (Pacheco, 2006). Some studies in Latin America do find evidence that access to credit favors deforestation-related activities over others (Barbier and Burgess, 1996; Pfaff, 1999). Focusing on Brazil, other papers find a strong positive correlation between agricultural credit and deforestation rates (Andersen, 1996; Angelsen and Kaimowitz, 1999; Hargrave and Kis-Katos, 2012). In 2008, Brazil decided to restrict access to credit in municipalities that are blacklisted because of their high rates of deforestation. Some studies argue that the curbing of deforestation in the past few years is related to this initiative (Assunção *et al.*, 2013; Nepstad *et al.*, 2014). In contrast, credit may also ease the adoption of more capital-intensive agriculture, which is less forest-consuming (Angelsen, 1999, 2010; Caviglia-Harris, 2003). Moreover, in their studies on Bolivia and Honduras, Godoy *et al.* (1997) argue that families with better access to credit are less forest-dependent than others.

Government expenditures have also often been thought to have an impact on natural resource depletion (Faria, 1998; Gupta and Barman, 2009) and especially on deforestation (Angelsen and Kaimowitz, 1999; Geist and Lambin, 2001). Linkages between government expenditure and deforestation have been scrutinized when structural adjustment policies were implemented in the 1980s: scholars questioned the effect of cuts in public spending on governments' ability to protect the environment (e.g. Kaimowitz *et al.*, 1998). When public spending cuts consist in drastically reducing funding towards new agricultural settlements, migration towards the agricultural frontier is made more difficult (Kaimowitz, Thiele and Pacheco, 1999). Bulte, Damania, and López (2007) show that rural subsidies towards large farmers triggered deforestation in Latin America. Several authors have found evidence of the role of transport infrastructure on deforestation (e.g. Pfaff *et al.*, 2007). López, Galinato, and Islam (2011) draw attention on the effect of the level and composition of public spending on the environment. Finally, Galinato and Galinato (2016) present evidence of a positive impact of government spending on deforestation-induced CO2 emissions.

Our paper makes several contributions on the links between man-made capital and natural resource depletion. First, relying on the fact that macroeconomic variables may have non-homogenous sectoral impacts (Mallick, 2014), we theoretically present the conditions under which better access to man-made capital may lead to higher deforestation, which is a major case of natural resource depletion. In our case of interest, we argue that better access to man-made capital has a diverse impact on natural resource-intensive sectors (what we call deforestation-related activities) as well as other sectors. For instance, it has already been shown that forests can be used as safety nets when credit and insurance markets are incomplete (Delacote, 2007, 2009). In such cases, better access to credit may represent a substitute for the use of forests as natural capital. Alternatively, better access to credit markets relaxes credit constraints and may facilitate agricultural investments, which would possibly favor deforestation. As an illustration, Susanti and Maryudi (2016) show how access to credit helped to develop oil palm plantations, which is an important direct cause of deforestation in Indonesia.

Second, considering that access to credit and public expenditures are key factors of man-made capital accumulation, we examine precisely the joint effect of credit and public expenditures on forest losses. Relying on our theoretical model, we suspect that easing the access to man-made capital has an effect, whether negative or positive, on the deforestation process. Yet, access to capital through credit and public expenditures has been thus far overlooked at cross-national levels. Indeed, to date the literature on macroeconomic deforestation factors has been extended toward the analysis of trade (Leblois, Damette, and Wolfersberger, 2017), real exchange rate (Arcand, Guillaumont and Guillaumont Jeanneney, 2008), energy policies (Dixon *et al.*, 2016), fiscal and monetary policies (Combes *et al.*, 2015), timber harvesting (Damette and Delacote, 2011), quantile regressions (Damette and Delacote, 2012) and GDP (Choumert, Combes Motel and Dakpo, 2013).

In addition, we argue that assessing the impact of public expenditures (access to credit) on deforestation cannot be done without considering access to credit (public spending). Indeed, the link between credit and public spending is well established in the macroeconomic literature. On the one hand, a crowding-in effect *à la* Barro (Barro, 1990) could exist. Under this hypothesis, private production depends on both credit and productive government expenditures, which are considered as inputs to private production. The marginal productivity of private capital is therefore positively affected by public spending. According to Mallick (2001) fiscal policy can influence output positively through the effects of public sector investment on private investment. On the other hand, the possibility of a crowding-out effect can be put forward according to which an increase in public spending dries out the credit available to private agents.

The rest of this paper is organized as follows. Section 2 presents a simple model of substitutability and complementarity between deforestation and man-made capital. Section 3 presents the econometric analysis using a dynamic panel specification connecting credit and public expenditures to forest losses on a sample of developing countries. Section 4 concludes.

2 Theoretical model

2.1 Main hypotheses

In this section, we investigate the channels by which a better access to man-made capital may be related to deforestation. Consider a country, in which the representative agent (e.g. farmer) maximizes its net income. Net income is derived from the agents' economic activities that depend on its access to two types of assets: natural capital, through deforestation D, and made-man capital (henceforth called capital) K.[2] Man-made capital requires both credit and public spending, of which specific effects on forest losses will be identified in the empirical section.

Our theoretical intuition is that man-made capital has heterogenous impacts on economic sectors. More precisely, we consider here that sectors relying on natural capital evolve in a different way than sectors not relying on it. Thus, we distinguish two kinds of income. Income $A(D, K_D)$ comes from activities related to deforestation such as agricultural expansion, timber harvesting, fuelwood collection, etc. In contrast, income $O(K_O)$ comes from activities not related to deforestation: subsidies to direct consumption, agricultural intensification, trade and business, sustainable forest harvesting, off-farm activities, etc. δ is the share of capital allocated to deforestation-related activities, while $(1 - \delta)$ is the share of capital dedicated to deforestation-unrelated activities. Thus we have: $K_D = \delta K$ and $K_O = 1 - \delta K$. We assume here standard properties:[3]

$A_i \geq 0$, $A_{ii} \leq 0$, $\forall i = \{D, K_D\}$; $O_{K_O} \geq 0$ and $O_{K_O K_O} \leq 0$.

The costs of deforestation $c(D)$ and access to capital $c(K)$ are increasing and convex:

$c_i \geq 0, c_{ii} \geq 0 \ \forall i = \{D, K\}$

[2] Hereby we implicitly assume that labor supply is fixed, with constant wage, and has no direct implications on capital allocation.

[3] The subscripts refer to first and second derivatives.

The cost of access to natural capital is related to property rights, as well as to the availability of the resource: those costs are lower when forests are open access, higher when property rights are safe and well defined, higher when forests are a scarce resource.

Although we are in a static model here, the income and cost function can be considered in a cumulative and actualized way. Indeed, we are not interested in this paper in the dynamics of consumption and savings, but more on the allocation of investment. The trade-off between consumption and investment is implicitly taken into account in the cost functions, as they can be interpreted as opportunity costs borne by the agents. Therefore, the optimized levels of deforestation and capital allocation can be considered as steady-state variables and partial derivatives as responses to shocks. Further, Angelsen (1999) and Kerr, Talikoff and Sanchez (2000) show that the dynamic problem of deforestation can be analyzed as a static problem of maximizing the current profit under reasonable conditions (see Delacote and Angelsen (2015) for further explanations).

The representative agent's maximization problem is thus:

$$\max_{D,K,\delta} I(D,K,\delta) = A(D,\delta K) + O\big((1-\delta)K\big) - c(D) - c(K) \tag{1}$$

First-order conditions implicitly give the level of deforestation D^*, capital K^* and share of capital allocated to deforestation-related activities δ^*:

$$A_D - c_D = 0 \tag{1}$$

$$\delta A_{K_D} + (1-\delta)O_{K_O} - c_K = 0 \tag{2}$$

$$KA_{K_D} - KO_{K_O} = 0 \tag{3}$$

Equation (1) indicates that the marginal revenue drawn from deforestation is equal to its marginal cost. Equation (2) shows that capital K^* is chosen in order to equal marginal productivity and marginal cost of capital. Equation (3) defines the allocation of capital δ^*

as the equalization of the marginal productivity of capital between deforestation-related and deforestation-unrelated activities.

Substituting equations (1), (2) and (3), we obtain the following condition:

$$\frac{A_{K_D}}{c_K} = \frac{O_{K_O}}{c_K} = \frac{A_D}{c_D} \tag{4}$$

Equation (4) simply states that deforestation choices and capital allocation are made so that the marginal benefit/marginal cost ratio is equalized for each activity.

Our main argument is that an increase in domestic credit or in public spending would result in a decrease of the marginal cost of capital. This would have an impact both on the total level of capital used by the representative agent, but also on capital allocation between deforestation-related and deforestation-unrelated activities, and thus on the level of deforestation.

2.2 Characterising cases of complementary vs. substitution between man-made and natural capital

Using the implicit function theorem, it can be shown that the decrease in c_K will increase capital use K^*, if and only if:

$$A_{DK_D} > A_{K_D K_D} \frac{c_D}{c_K} - A_D \frac{c_{KK}}{\delta c_K} \equiv \overline{A_{DK_D}} \tag{5}$$

The share of capital allocated to deforestation activities will increase with the capital cost decrease if and only if:

$$A_{DK_D} > A_{K_D K_D} \frac{c_D}{c_K} \equiv \overline{\overline{A_{DK_D}}} \tag{6}$$

Overall, it is easy to show that a capital cost decrease tend to increase capital allocated to deforestation ($K_D = \delta K$) if:

$$A_{DK_D} > \overline{A_{DK_D}} \tag{7}$$

Note that $\overline{\overline{A_{DK_D}}} < \overline{A_{DK_D}} < 0$. It follows that the decrease in the cost of access to capital may increase the capital allocated to deforestation, even if this increase tend to decrease the marginal productivity of capital (i.e. $A_{DK_D} < 0$). This is due to the decreasing marginal productivity of capital, and the capital cost function convexity.

However, even if capital allocated to deforestation increases, this does not mean deforestation itself increases. Indeed, this is done only if:

$$A_{DK_D} > A_{DD}\frac{c_K}{c_D} - A_{K_D}\frac{c_{DD}}{c_D} \equiv \overline{\overline{\overline{A_{DK_D}}}} \tag{8}$$

It is interesting to note that $\overline{\overline{\overline{A_{DK_D}}}}$ may be larger or smaller than $\overline{A_{DK_D}}$. Several cases may then happen:

$\overline{A_{DK_D}} < \overline{\overline{\overline{A_{DK_D}}}} < A_{DK_D}$, the decrease in c_K increases capital allocated to deforestation and the amount of deforestation.

$\overline{A_{DK_D}} < A_{DK_D} < \overline{\overline{\overline{A_{DK_D}}}}$, the decrease in c_K increases capital allocated to deforestation but decreases the total amount of deforestation. We have here a case of *capitalized* deforestation: deforestation is smaller but more capital intensive.

$A_{DK_D} < \overline{A_{DK_D}} < \overline{\overline{\overline{A_{DK_D}}}}$, the decrease in c_K decreases both capital allocated to deforestation and the total amount of deforestation.

The first case is more likely than the two other ones. For instance, Bulte, Damania, and López (2007) assume factor complementarity in Brazilian landowners' production function. One could argue that countries with large forest endowments are more likely to experience complementarity between man-made and natural capital. Indeed, the conversion costs are smaller for countries with larger forest endowments, and access to natural capital is thus facilitated. Moreover, countries with a strong reliance on agricultural sectors and natural resource harvesting are also more likely to experience complementarity: man-made capital tends to be allocated to agricultural activities which are sources of agricultural expansion and deforestation. Developing countries frequently present those two characteristics. For those two reasons, man-made capital is more likely to be allocated to deforestation-related activities in those countries. In section 3, we will thus consider that observing a positive relationship between deforestation and access to capital describes a situation of complementarity between natural capital and made-man capital, while a situation of substitutability will be considered in the case of a negative relationship.

3 The empirical analysis of forest cover loss, credit, and public spending

The theoretical model of Section 2 presents the conditions under which better access to man-made capital can foster deforestation and gives the intuition that developing countries may fit those conditions. This section is precisely meant to empirically evidence whether this case for complementarity is not econometrically rejected for developing countries, which shelter important stocks of forests and where this type of natural capital accounts for an important part of their natural wealth. This empirical investigation deserves further, say auxiliary, assumptions that are described in section 3.1. After having presented the dataset (section 3.2), we present and discuss the results in section 3.3.

3.1 Econometric model

We adopt a dynamic panel specification identifying the specific impact of two determinants of man-made capital, domestic credit, and public spending, on forest losses. We argue here that domestic credit and public spending ease the access to man-made capital. Besides, the effect of control variables as put forward in the applied literature on deforestation drivers, are also taken into account.

3.1.1 Dynamic specification

The theoretical model is static. However, as mentioned, this static description of capital allocation of deforestation can be interpreted as steady-state conditions. For that manner, the adequate econometric specification leads us to assume that there exists a steady state value of the logarithm of forest loss-- say $\ln FLoss_i^*$ - where i denotes the country. Let us define the gap between the logs of forest loss for country i in year t and its steady state value as $z_{it} \equiv \ln FLoss_{it} - \ln FLoss_{it}^*$. Next, let us assume that the dynamics of z is described by a first order linear homogenous differential equation: $\dot{z} = -\beta z$ with $0 < \beta < 1$. This expresses that the rate of convergence of forest loss $FLoss$ towards its steady state value decreases at rate β. After some calculations, solving this equation gives the basic dynamic specification of forest loss:[4]

$$\ln FLoss_{it} \cong \beta \ln FLoss_{it}^{*} + (1-\beta) \ln FLoss_{it-1}$$

This specification introduces a restriction on the coefficient of the lagged dependent variable which is written as $0 < 1-\beta < 1$. In addition, we assume that $FLoss_{it}^{*}$ depends on variables suggested by the theoretical framework, and control variables that catch underlying drivers of deforestation as well as determinants of agricultural profitability.

3.1.2 Interest and control variables

Taking our interest and control variables into account, the dynamic specification becomes:

$$\ln FLoss_{it} = \alpha_0 + \alpha_i + (1-\beta) \ln FLoss_{it-1} + \gamma_1 \ln Exp_{it} + \gamma_2 \ln Cred_{it} + X_{it}'\delta + \varepsilon_{it} \tag{10}$$

In equation 10, $FLoss_{it}$ refers to the current value of forest loss in hectares in country i in year t. α_i is a country fixed effect and ε_{it} is the error term.

Public spending (Exp_{it}) and domestic credit ($Cred_{it}$) are our interest variables. They both proxy the provision of man-made capital. Indeed, an increase in public spending (domestic credit) will decrease the cost of public capital (private capital). An increase in Exp and $Cred$ therefore leads to more deforestation if the available funds are allocated to deforestation activities (e.g. agriculture, dam or road construction). Put differently, we expect a positive effect of these variables on deforestation i.e. $\gamma_1 > 0$ and $\gamma_2 > 0$.

X_{it}' is a vector of control variables including *GDP per capita* in logs and its squared value, *Population*; *Government stability* as a proxy of institutional quality; and *Temperature* and *Rainfall shocks,* which account for the potential effect of climate variability on deforestation.

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[4] The general solution of $\dot{z}_{it} = -\beta z_{it}$ is $z_{it} = z_{it_0} e^{-\beta(t-t_0)}$ that is, i.e., $\ln FLoss_{it} - \ln FLoss_{it}^{*} = (\ln FLoss_{it_0} - \ln FLoss_{it}^{*}) e^{-\beta(t-t_0)}$ Rearranging terms gives: $\ln FLoss_{it} = \ln FLoss_{it_0} e^{-\beta(t-t_0)} + \ln FLoss_{it}^{*} \left(1 - e^{-\beta(t-t_0)}\right)$. Then, linearizing $e^{-\beta(t-t_0)}$ around t_0 gives: $e^{-\beta(t-t_0)} \cong 1 - \beta(t-t_0)$. Setting $t_0 = t-1$ finally yields our basic dynamic specification, which is written as $\ln FLoss_{it} \cong \beta \ln FLoss_{it}^{*} + (1-\beta) \ln FLoss_{it-1}$.

Based on the Environmental Kuznets Curve (EKC), GDP per capita and GDP per capita squared should respectively influence forest loss positively and negatively. Nevertheless, as shown in Choumert, Combes Motel, and Dakpo (2013), existing studies provide ambiguous results. For instance, several authors find evidence of an EKC for deforestation (e.g. Bhattarai and Hammig, 2001; Culas, 2007) while others do not (e.g. Meyer, van Kooten and Wang, 2003). The expected impact of population is also ambiguous. An increase in population fuels the demand for arable lands, fuelwood and charcoal, which can foster deforestation (Cropper and Griffiths, 1994). The relationship between forest resources and population can be far more complex when it is addressed in a general equilibrium framework: the demand for forest products associated with population and income growth have been found to generate forest expansion (Foster and Rosenzweig, 2003). Then, better institutions are assumed environmentally friendly, *i.e.*, they can also preserve forests, as documented in the literature (e.g. Bhattarai and Hammig, 2001; Ferreira, 2004; Ferreira and Vincent, 2010). However, this effect can be counteracted if good quality institutions secure property rights. In such cases, better institutions may favor productive investments (Besley, 1995) that potentially encroach on forested areas. Therefore, the overall effect of better institutions is also likely to be ambiguous. Finally, climate variables are deemed to control for the profitability of agriculture as well as for natural causes underlying forest losses. It is argued here that shocks must be considered in the period under study, which is characterized by anomalies with respect to long-term trends. For instance, extreme temperatures and low precipitations can be harmful to plants, leading to a loss of forest cover. On the other hand, strong climate variability may increase environmental awareness and ultimately result in less deforestation. The expected effect is thus likely to be ambiguous.

3.1.3 Econometric method: System-GMM Estimator

Regarding the estimation of equation 10, since the lagged dependent variable appears on the right-hand side, the OLS estimator is biased due to the correlation with the error term (Nickell, 1981). In order to deal with this issue, we use the extended System-GMM coined by Blundell and Bond (1998) where the equation in levels is combined with the equation in differences in a system of equations. In this case, lagged variables in levels and lagged variables in differences are used as instruments. This approach has the advantage of addressing both the issue of endogeneity and the issue of unobserved heterogeneity. In addition, this estimator is preferred over the standard first difference GMM because if the dependent variable is close to a random walk process, then variables in levels are poor instruments of the variables in differences. The System-GMM helps address this weak instrument issue and above all has better finite sample properties. We will, therefore, assume that together our two interest variables are weakly exogenous.

3.2 Dataset

The data on forests used in this study is the outcome of remote sensing methods. The dataset comes from the Department of Geographical Science of the University of Maryland and was first published by Hansen *et al.* (2013). This dataset relies on a land cover definition while the FAO's definition is based on a land use approach (Keenan *et al.*, 2015). Forest cover loss is defined as a "stand-replacement disturbance or a change from a forest to a non-forest state" (Hansen *et al.*, 2013). It, therefore, encompasses the conversion of forest cover to non-forest cover whenever the conversion is induced by natural and human causes (Hansen, Stehman and Potapov, 2010).[5] Forest cover loss is obtained using earth observation satellite data at a spatial resolution of 30 meters. One main implication of exploiting this dataset is using different measures of forest cover since the extent of forest is sensitive to the threshold of tree cover (Sexton *et al.*, 2016): different types of forest are categorized according to a threshold of canopy cover expressed in percentages. It allows making a distinction between closed forests (highest percentages) and open forests (lower percentages). In tropical countries, the highest percentages of forest cover correspond broadly to tropical moist forests. It must be noted that net forest cover variations cannot be computed since losses and gains are not comparable owing to the measurement methodology. This dataset on forest cover loss is deemed more reliable and improves on the existing FAO data on forest cover of which quality has been questioned (Grainger, 2008). Yet measurement errors in forest cover loss may still exist. It is however assumed: (i) that they are caught by country fixed effects; (ii) provided they are randomly distributed, they collapse into the error term.

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[5] Forest loss is used instead of deforestation in the sense defined by Hansen et al.(2013) according to which forest loss includes "deforestation, fire, and logging within the course of sustainable forestry operations."

Public spending Exp is measured by the general government consumption expenditure in percentages of GDP. Credit $Cred$ is measured by the domestic credit provided by the banking sector in percentages of GDP. Other socio-economic variables are drawn from the World Development Indicators. Government stability is extracted from the International Country Risk Guide (ICRG) database. Climate data are from the Climatic Research Unit (CRU) of the University of East Anglia. They allow for calculating indices of climate shocks, which are defined as the deviation of the yearly average of climate (temperature, rainfall) from its long-term trend (mean of rainfall 1901-2012).

Since our theoretical model was designed in the context of developing countries, we construct a sample of 63 countries located in Sub-Saharan Africa, Latin America, and Asia. These samples cover the period 2001 to 2012. All variables' definitions and descriptive statistics, as well as lists of countries, are provided in Table 1 and Table 2 in the Appendix.

3.3 Results

Basic results of equation (10) are all reported in Table 3 and Table 4: the dependent variable corresponds to the broader definition of forest cover, *i.e.*, forest cover with a threshold of tree cover greater than 10%. Table 3 presents results that include all developing countries whatever their initial forest coverage, whereas Table 4 presents results from developing countries with forested areas in 2000 above 5% of the country's surface area. These basic results are presented in three steps: we focus first on the forest loss dynamics (Section 3.3.1), and then on drivers of deforestation (Section 3.3.2). The final step is devoted to the tests of our theoretical predictions (Section 3.3.3). Basic results are completed by a robustness analysis, which allows checking the sensitivity of the results to the definition of forest and to an alternative proxy of man-made capital (Section 3.3.4).

3.3.1 Forest loss dynamics

Checking the characteristics of forest loss dynamics relies on several preliminary tests pertaining to the econometric hypothesis attached to the dynamic panel estimator. First, the Sargan / Hansen overidentification test indicates that the instruments are not correlated with the error term and therefore does not reject their validity. Second, the null hypothesis of no second-order serial correlation of the error term is not rejected at the

5% level. This ensures that the hypothesis of serial independence in the error term ε_{it} of equation 10 is not invalidated. The second lags of explanatory variables can therefore be considered as appropriate instruments for their current values since they are not correlated with the error term. Lastly, the number of instruments does not exceed the number of countries, which ensures that the problem of instrument proliferation is avoided (Roodman, 2009).

Results reported in Table 3 and Table 4 illustrate the characteristics of the dynamic process at work in forests. We find that the coefficient (β) of the lagged dependent variable is significantly different from zero. A Chi2 statistic ensures that β is lower than 1. In short, the estimated β belongs to the [0; 1] interval. We, therefore, find that all else equal, the world's forest losses are governed by a stationary AR(1) process. This corroborates the pervasive character of gross forest loss coined in earlier studies (Hansen, Stehman and Potapov, 2010). Considering the most complete specifications (column 4 in Table 3 and column 3 in Table 4), results show that a past 1% increase in forest loss induces a 0.64 to 0.57 percent increase in current forest loss in developing countries.

These results also allow stating that forest loss converges towards a steady-state value. It is worth remembering that the data measure gross forest lost: they do not account for forest gains, which could potentially compensate for forest losses. Our results cannot be interpreted as going against the forest transition theory (Barbier, Delacote and Wolfersberger, 2017).

Table 3 about here

Table 4 about here

3.3.2 Controlling for drivers of deforestation

Deforestation is the result of multiple and complex relationships. In this paper, we attempt to catch underlying causes as coined by Angelsen and Kaimowitz (1999), as well as climatic factors. It is noted here that country fixed effects catch unobservable time-invariant structural characteristics such as geographical characteristics. Whatever the specifications, the EKC hypothesis cannot be rejected, which is in contrast with existing mixed EKC results for deforestation. Depending on the specification, the curve inverts when GDP per capita in developing countries reaches about 4,200 to 4,300 U.S. dollars, which leaves less than one-fourth of the countries beyond that level.

The population also has a positive and significant impact on forest loss.[6] This supports the idea that forests are cleared under the pressure of agricultural land expansion or for charcoal provision purposes, which are fuelled by the size of the population. This result is somehow in line with the IPAT identity according to which environmental degradation is positively linked with population size (Ehrlich and Holdren, 1971). The proxy of the quality of institutions (*Government stability*) is found to be insignificant. The rationale for this result might be justified by econometric and economic arguments. Indeed, the quality of institutions is correlated with GDP per capita. In addition, the period under study is likely not affected by drastic changes in the quality of institutions. As for economic explanations, the quality of institutions has an ambiguous effect on deforestation, as previously discussed. Finally, climate shocks do not have a clear impact on forest loss though anomalies in temperatures have increased over recent years.

3.3.3 Does access to man-made capital foster natural capital depletion?

The estimated coefficients γ_1 and γ_2 associated with variables Exp and $Cred$ from equation (10) are positive and significant. It is worth to notice that γ_1 and γ_2 are marginal effects that can also be interpreted as elasticities according to our specification. The positive effect of Exp and $Cred$ on forest loss is positive whenever they are separately introduced (columns 1 and 2 in Table 3 and Table 4) or jointly introduced (columns 3 and 4 in Table 3 and Table 4).[7] Results are especially significant for countries with a substantial initial forested area in 2000 (Table 4). Considering our theoretical model presented in section 2, these results can be interpreted as exhibiting a complementary effect between man-made capital and natural capital.

[6] We substituted the Population variable with Population density. Results, which are not reported here, do not differ significantly though the Population density variable is seldom found significant.

[7] We investigated conditional effects while introducing an interactive term $\ln Exp \times \ln Cred$. The interactive term is not significant. Conditional effects calculated at different values of the interacted term do not differ significantly from estimates reported in Tables 3 and 4. Results are available upon request from the authors.

Based on the most complete specification (column 3) of Table 4, the elasticity of forest loss with respect to government expenditure (γ_1) amounts to 14 percentage points while the figure is 8 for credit (γ_2) in developing countries.

Table 3 about here

Table 4 about here

3.3.4 Robustness analysis

3.3.4.1 Sensitivity to the forest definition

A robustness analysis is performed using data on forest losses that are categorized by threshold percentages of canopy cover: instead of considering losses that occurred on forests whose tree canopy cover was at least 10%, we use narrower definitions of forest cover, *i.e.*, with higher canopy density as measured by different threshold measures of tree cover. The rationale of this robustness check is to determine whether our results still hold in areas hosting closed forests, which are supposedly less prone to human encroachment.

Table 5 reports results for increasing canopy density. The results do not change substantially. The magnitude of the elasticity of forest loss with respect to government expenditures does not change much along increasing forest canopy density. A notable exception is the *Population* variable, which becomes insignificant. More dense forests (with the highest canopy density), are core forests that are likely to be located in remote areas where population pressure on deforestation is lower (Angelsen and Rudel, 2013). Furthermore, forest loss is increasingly sensitive to domestic credit (see columns 5 and 6). The complementary effect between man-made capital and natural capital is thus reinforced, which should call for stronger public intervention to pay higher attention to the detrimental influence of better access to credit in environmentally sensitive areas such as closed forests. Better access to credit, which is generally considered a desirable feature in developing countries, should be balanced against potential negative environmental effects.

Table 5 about here

3.3.4.2 Sensitivity to the measure of man-made capital

It can be suspected that the interest variables *Exp* and *Cred* catch the effect of an increase in the demand for forestry products rather than an increase in man-made capital on natural capital. Though this consumption effect might be controlled by variables such as GDP per capita, the effect of another proxy for man-made capital is worth being taken into account.[8] Gross capital formation(GFC) seems a reasonable choice since data are available on a wide set of developing countries. Results show that our main theoretical predictions are not affected by this alternative measure of man-made capital (Table 6). The elasticity of forest loss with respect to GFC amounts from 7 (column 1) to 13 percentage points (column 2). Table 7 is consistent with those results while varying the canopy density.

Table 6 about here

Table 7 about here

[8] We are thankful to an anonymous referee for having drawn our attention on this.

4 Concluding remarks

Building capital is an important goal of economic development, and financial development is a way to achieve it. Public spending and domestic credit crucially influence man-made capital. Deforestation and land-use change are examples of the use of natural capital to achieve development objectives. Man-made capital as a means of development may thus be built at the expense of natural assets such as tropical forests. It follows that assessing the relationship between these different forms of capital is a crucial task.

In this paper, a simple theoretical framework is built that explores the complex relationship between man-made capital, as favored by financial development and public spending, and deforestation. Our intuition is that man-made capital accumulation has a non-homogenous impact on sectors relying on natural capital and sectors non-relying on natural capital. We show that man-made capital can foster deforestation when it is a complement to natural capital. In this case, easier access to credit and higher public spending are more likely to be allocated to deforestation-related activities, which creates a case for an environment-development trade-off. An econometric analysis, on a sample of developing countries, finds results, which are in line with the theory: increased access to credit and public spending seems to boost deforestation-related activities. In this context, man-made capital and natural capital are to be considered as complements more than as substitutes.

Our results suggest potential limits to economic development when natural resources become scarce, especially when sources of substitutability between the two forms of capital are not found. An important research recommendation here is to deepen the analysis of this complementarity, to find potential sources of substitutability, and to understand the dynamics of transition from a situation of complementarity to a situation of substitutability. Indeed, it is important to understand in what context better access to credit - a crucial development requisite - is not achieved at the expense of forest depletion. This research is in line with previous attempts aiming at theoretically investigating the linkages between macroeconomic policies and the environment.[9] Disentangling the access to man-made capital as a way to boost depletion of natural capital is thus essential. Another research recommendation is related to composition effects generated by public spending and credit. Identifying the components of public spending and what loan beneficiary characteristics are fueling deforestation, is a crucial issue from a policy perspective.

In terms of policy recommendations, our results can be interpreted as evidence of the existence of a Tinbergen rule: at least one policy instrument is needed for each policy objective. Reducing the threat on forests is not likely to come indirectly from better access to credit and public spending unless further efforts are made to redirect investment into non-deforestation related activities. For instance, economic incentives (taxes or subsidies) increasing the cost of deforestation-related activities or increasing the profitability of activities not related to deforestation should be combined with a better access to credit. Public spending should also target activities with smaller environmental impacts. In the same manner, our study supports the Brazilian initiative to restrict access to credit to municipalities that are blacklisted because of their high rates of deforestation (Assunção *et al.*, 2013; Nepstad *et al.*, 2014; Cisneros, Zhou and Börner, 2015). Environmental instruments need to be combined with traditional economic instruments in the achievement, for instance, of the Sustainable Development Goals.

These recommendations must be considered in the light of development policies. According to Humphreys (2006), the World Bank has long considered forests as an abundant and under-harvested asset. Therefore, development policies focused on the need for developing countries to build access to capital in order to develop forest-related activities. By contrast, since the 1990s, the World Bank has seemed to take into consideration the complementarity between natural and man-made assets. In this sense, the strategy around forests has been to focus on the development of markets for goods and services (NTFP, carbon sequestration, eco-tourism), which could be described in our model as non-deforestation related activities. At the same time, the focus has been made on decreasing expected profitability of deforestation-related activities (timber

[9] Examples of this strand of the literature are Heyes (2000) or Combes *et al.* (2015).

certification, for instance). One next step of development agencies would be to take explicitly into account the channels of diffusion of public spending and better access to credit by providing incentives for pursuing non-deforestation-related activities.

5 References

Andersen, L. E. (1996) 'The Causes of Deforestation in the Brazilian Amazon', *The Journal of Environment & Development*, 5(3), pp. 309–328. doi: 10.1177/107049659600500304.

Angelsen, A. (1999) 'Agricultural expansion and deforestation: modelling the impact of population, market forces and property rights', *Journal of Development Economics*, 58(1), pp. 185–218. doi: 10.1016/S0304-3878(98)00108-4.

Angelsen, A. (2010) 'Policies for reduced deforestation and their impact on agricultural production', *Proceedings of the National Academy of Sciences*, 107(46), pp. 19639–19644. doi: 10.1073/pnas.0912014107.

Angelsen, A. and Kaimowitz, D. (1999) 'Rethinking the Causes of Deforestation: Lessons from Economic Models', *The World Bank Research Observer*, 14(1), pp. 73–98.

Angelsen, A. and Rudel, T. K. (2013) 'Designing and Implementing Effective REDD + Policies: A Forest Transition Approach', *Review of Environmental Economics and Policy*, 7(1), pp. 91–113. doi: 10.1093/reep/res022.

Antle, J. M., Stoorvogel, J. J. and Valdivia, R. O. (2006) 'Multiple equilibria, soil conservation investments, and the resilience of agricultural systems', *Environment and Development Economics*, 11(04), pp. 477–492. doi: 10.1017/S1355770X06003056.

Arcand, J.-L., Guillaumont, P. and Guillaumont Jeanneney, S. (2008) 'Deforestation and the real exchange rate', *Journal of Development Economics*, 86(2), pp. 242–262. doi: 10.1016/j.jdeveco.2007.02.004.

Assunção, J. *et al.* (2013) *Does Credit Affect Deforestation? Evidence from a Rural Credit Policy in the Brazilian Amazon*. Climate Policy Initiative. Available at: https://www.illegal-logging.info/sites/files/chlogging/uploads/DoesCreditAffectDeforestationEvidencefromaRuralCreditPolicyintheBrazilianAmazonTechnicalPaperEnglish.pdf.

Ayres, R. U., van den Bergh, J. C. J. M. and Gowdy, J. M. (1998) 'Viewpoint: weak versus strong sustainability'. Available at: http://dare.ubvu.vu.nl/bitstream/1871/9295/1/98103.pdf.

Azqueta, D. and Sotelsek, D. (2007) 'Valuing nature: From environmental impacts to natural capital', *Ecological Economics*, 63(1), pp. 22–30. doi: 10.1016/j.ecolecon.2007.02.029.

Barbier, E. B. (2011) 'The policy challenges for green economy and sustainable economic development', *Natural Resources Forum*, 35(3), pp. 233–245. doi: 10.1111/j.1477-8947.2011.01397.x.

Barbier, E. B. and Burgess, J. C. (1996) 'Economic analysis of deforestation in Mexico', *Environment and Development Economics*, 1(2), pp. 203–239. doi: 10.1017/S1355770X00000590.

Barbier, E. B., Delacote, P. and Wolfersberger, J. (2017) ‘The economic analysis of the forest transition: A review’, *Journal of Forest Economics*, 27, pp. 10–17. doi: 10.1016/j.jfe.2017.02.003.

Barro, R. J. (1990) ‘Government Spending in a Simple Model of Endogeneous Growth’, *The Journal of Political Economy*, 98(5), pp. S103–S125.

Besley, T. (1995) ‘Property Rights and Investment Incentives: Theory and Evidence from Ghana’, *The Journal of Political Economy*, 103(5), pp. 903–937.

Bhattarai, M. and Hammig, M. (2001) ‘Institutions and the Environmental Kuznets Curve for deforestation: a crosscountry analysis for Latin America, Africa and Asia’, *World Development*, 29(6), pp. 995–1010.

Blundell, R. and Bond, S. (1998) ‘Initial conditions and moment restrictions in dynamic panel data models’, *Journal of Econometrics*, 87(1), pp. 115–143. doi: 10.1016/S0304-4076(98)00009-8.

Bretschger, L. and Smulders, S. (2012) ‘Sustainability and substitution of exhaustible natural resources’, *Journal of Economic Dynamics and Control*, 36(4), pp. 536–549. doi: 10.1016/j.jedc.2011.11.003.

Bulte, E. H., Damania, R. and López, R. E. (2007) ‘On the gains of committing to inefficiency: Corruption, deforestation and low land productivity in Latin America’, *Journal of Environmental Economics and Management*, 54(3), pp. 277–295. doi: 10.1016/j.jeem.2007.05.002.

Caviglia-Harris, J. L. (2003) ‘Sustainable Agricultural Practices in Rondônia, Brazil: Do Local Farmer Organizations Affect Adoption Rates?’, *Economic Development and Cultural Change*, 52(1), pp. 23–49.

Celentano, D. *et al.* (2012) ‘Welfare Outcomes and the Advance of the Deforestation Frontier in the Brazilian Amazon’, *World Development*, 40(4), pp. 850–864. doi: 10.1016/j.worlddev.2011.09.002.

Choumert, J., Combes Motel, P. and Dakpo, H. K. (2013) ‘Is the Environmental Kuznets Curve for deforestation a threatened theory? A meta-analysis of the literature’, *Ecological Economics*, 90, pp. 19–28. doi: 10.1016/j.ecolecon.2013.02.016.

Cisneros, E., Zhou, S. L. and Börner, J. (2015) ‘Naming and Shaming for Conservation: Evidence from the Brazilian Amazon’, *PLoS ONE*, 10(9), p. e0136402. doi: 10.1371/journal.pone.0136402.

Cleveland, C. J. and Ruth, M. (1997) ‘When, where, and by how much do biophysical limits constrain the economic process?: A survey of Nicholas Georgescu-Roegen’s contribution to ecological economics’, *Ecological Economics*, 22(3), pp. 203–223. doi: 10.1016/S0921-8009(97)00079-7.

Combes, J.-L. *et al.* (2015) ‘Deforestation and seigniorage in developing countries: A tradeoff?’, *Ecological Economics*, 116, pp. 220–230. doi: 10.1016/j.ecolecon.2015.03.029.

Cropper, M. and Griffiths, C. (1994) ‘The interaction of population growth and environmental quality’, *The American Economic Review*, 84(2), pp. 250–254.

Culas, R. J. (2007) ‘Deforestation and the environmental Kuznets curve: An institutional perspective’, *Ecological Economics*, 61(2–3), pp. 429–437. doi: 10.1016/j.ecolecon.2006.03.014.

Daly, H. E. (1994) ‘Fostering environmentally sustainable development: four parting suggestions for the World Bank’, *Ecological Economics*, 10(3), pp. 183–187. doi: 10.1016/0921-8009(94)90106-6.

Daly, H. E. (1997) ‘Georgescu-Roegen versus Solow/Stiglitz’, *Ecological Economics*, 22(3), pp. 261–266. doi: 10.1016/S0921-8009(97)00080-3.

Daly, H. E. and Townsend, K. N. (eds) (1993) *Valuing the earth: economics, ecology, ethics*. MIT Press.

Damette, O. and Delacote, P. (2011) ‘Unsustainable timber harvesting, deforestation and the role of certification’, *Ecological Economics*, 70(6), pp. 1211–1219. doi: 10.1016/j.ecolecon.2011.01.025.

Damette, O. and Delacote, P. (2012) ‘On the economic factors of deforestation: What can we learn from quantile analysis?’, *Economic Modelling*, 29(6), pp. 2427–2434. doi: 10.1016/j.econmod.2012.06.015.

Dasgupta, P. S. (2007) ‘Nature in Economics’, *Environmental and Resource Economics*, 39(1), pp. 1–7. doi: 10.1007/s10640-007-9178-4.

Dasgupta, P. S. and Heal, G. (1974) ‘The Optimal Depletion of Exhaustible Resources’, *The Review of Economic Studies*, 41, pp. 3–28.

Delacote, P. (2007) ‘Agricultural Expansion, Forest Products as Safety Nets, and Deforestation’, *Environment and Development Economics*, 12(02), pp. 235–249. doi: 10.1017/S1355770X06003482.

Delacote, P. (2009) ‘Commons as insurance: safety nets or poverty traps?’, *Environment and Development Economics*, 14(3), pp. 305–322. doi: 10.1017/S1355770X08004993.

Delacote, P. and Angelsen, A. (2015) ‘Reducing Deforestation and Forest Degradation: Leakage or Synergy?’, *Land Economics*, 91(3), pp. 501–515. doi: 10.3368/le.91.3.501.

Diamond, J. (2013) *Collapse: How Societies Choose to Fail or Survive*. Penguin UK.

Dixon, P. *et al.* (2016) ‘RED versus REDD: Biofuel policy versus forest conservation’, *Economic Modelling*, 52, pp. 366–374. doi: 10.1016/j.econmod.2015.09.014.

Ehrlich, P. R. and Holdren, J. P. (1971) ‘The Impact of Population Growth’, *Science*, 171(3977), pp. 1212–1217.

England, R. W. (2000) ‘Natural capital and the theory of economic growth’, *Ecological Economics*, 34(3), pp. 425–431. doi: 10.1016/S0921-8009(00)00187-7.

Faria, J. R. (1998) ‘Environment, growth and fiscal and monetary policies’, *Economic Modelling*, 15(1), pp. 113–123.

Ferreira, S. (2004) ‘Deforestation, Property Rights, and International Trade’, *Land Economics*, 80(2), pp. 174–193. doi: 10.2307/3654737.

Ferreira, S. and Vincent, J. R. (2010) ‘Governance and Timber Harvests’, *Environmental and Resource Economics*, 47(2), pp. 241–260. doi: 10.1007/s10640-010-9374-5.

Foster, A. D. and Rosenzweig, M. R. (2003) ‘Economic Growth and the Rise of Forests’, *The Quarterly Journal of Economics*, 118(2), pp. 601–637.

Galinato, G. I. and Galinato, S. P. (2016) ‘The effects of government spending on deforestation due to agricultural land expansion and CO2 related emissions’, *Ecological Economics*, 122, pp. 43–53. doi: 10.1016/j.ecolecon.2015.10.025.

Geist, H. J. and Lambin, E. F. (2001) *What drives tropical deforestation? A meta-analysis of proximate and underlying causes of deforestation based on subnational case study evidence*. Louvain-la-Neuve: LUCC International Project Office - University of Louvain (LUCC Report Series, 4). Available at: http://www.pik-potsdam.de/members/cramer/teaching/0607/Geist_2001_LUCC_Report.pdf.

van Geldrop, J. and Withagen, C. A. (2000) ‘Natural capital and sustainability’, *Ecological Economics*, 32(3), pp. 445–455. doi: 10.1016/S0921-8009(99)00121-4.

Godoy, R. *et al.* (1997) ‘Household determinants of deforestation by amerindians in honduras’, *World Development*, 25(6), pp. 977–987. doi: 10.1016/S0305-750X(97)00007-7.

Grainger, A. (2008) ‘Difficulties in tracking the long-term global trend in tropical forest area’, *Proceedings of the National Academy of Sciences of the United States*, 105(2), pp. 818–823. doi: 10.1073/pnas.0703015105.

Gupta, M. R. and Barman, T. R. (2009) ‘Fiscal policies, environmental pollution and economic growth’, *Economic Modelling*, 26(5), pp. 1018–1028. doi: 10.1016/j.econmod.2009.03.010.

Hansen, M. C. *et al.* (2013) ‘High-Resolution Global Maps of 21st-Century Forest Cover Change’, *Science*, 342(6160), pp. 850–853. doi: 10.1126/science.1244693.

Hansen, M. C., Stehman, S. V. and Potapov, P. V. (2010) ‘Quantification of global gross forest cover loss’, *Proceedings of the National Academy of Sciences of the United States of America*, 107(19), pp. 8650–8655. doi: 10.1073/pnas.0912668107.

Hargrave, J. and Kis-Katos, K. (2012) ‘Economic Causes of Deforestation in the Brazilian Amazon: A Panel Data Analysis for the 2000s’, *Environmental and Resource Economics*, 54(4), pp. 471–494. doi: 10.1007/s10640-012-9610-2.

Heyes, A. (2000) ‘A proposal for the greening of textbook macro: “IS-LM-EE”’, *Ecological Economics*, 32(1), pp. 1–7. doi: 10.1016/S0921-8009(99)00097-X.

Humphreys, D. (2006) *Logjam: Deforestation and the crisis of global governance*. Cambridge University Press (The Earthscan Forest Library).

Kaimowitz, D. *et al.* (1998) 'Considering the impact of structural adjustment policies on forests in Bolivia, Cameroon and Indonesia'. (Unasylva), 49(194). Available at: http://www.fao.org/docrep/w8827e/w8827e0a.htm (Accessed: 1 February 2018).

Kaimowitz, D., Thiele, G. and Pacheco, P. (1999) 'The Effects of Structural Adjustment on Deforestation and Forest Degradation in Lowland Bolivia', *World Development*, 27(3), pp. 505–520. doi: 10.1016/S0305-750X(98)00146-6.

Keenan, R. J. *et al.* (2015) 'Dynamics of global forest area: Results from the FAO Global Forest Resources Assessment 2015', *Forest Ecology and Management*. (Changes in Global Forest Resources from 1990 to 2015), 352, pp. 9–20. doi: 10.1016/j.foreco.2015.06.014.

Kerr, S., Talikoff, A. S. P. and Sanchez, A. (2000) *The dynamics of deforestation: evidence from Costa Rica*. Columbia University Academic Commons. Available at: https://doi.org/10.7916/D8MK6R53.

Krautkraemer, J. A. (2005) *Economics of Natural Resource Scarcity. The State of the Debate*. Discussion Paper 05–14. Washington D.C.: Resources for the Future. Available at: http://www.rff.org/rff/Documents/RFF-DP-05-14.pdf.

Leblois, A., Damette, O. and Wolfersberger, J. (2017) 'What has Driven Deforestation in Developing Countries Since the 2000s? Evidence from New Remote-Sensing Data', *World Development*, 92, pp. 82–102. doi: 10.1016/j.worlddev.2016.11.012.

López, R. E., Galinato, G. I. and Islam, A. (2011) 'Fiscal spending and the environment: Theory and empirics', *Journal of Environmental Economics and Management*, 62(2), pp. 180–198. doi: 10.1016/j.jeem.2011.03.001.

Mallick, S. K. (2001) 'Dynamics of Macroeconomic Adjustment with Growth: Some Simulation Results', *International Economic Journal*, 15(1), pp. 115–139. doi: 10.1080/10168730100000006.

Mallick, S. K. (2014) 'Disentangling the Poverty Effects of Sectoral Output, Prices, and Policies in India', *Review of Income and Wealth*, 60(4), pp. 773–801. doi: 10.1111/roiw.12026.

Meadows, D. H., Randers, J. and Meadows, D. L. (2005) *The Limits to Growth: The 30-year Update*. Revised edition. London: Earthscan.

Meyer, A. L., van Kooten, G. C. and Wang, S. (2003) 'Institutional, social and economic roots of deforestation: a cross-country comparison', *International Forestry Review*, 5(1), pp. 29–37. doi: 10.1505/IFOR.5.1.29.17427.

Nepstad, D. *et al.* (2014) 'Slowing Amazon deforestation through public policy and interventions in beef and soy supply chains', *Science*, 344(6188), pp. 1118–1123. doi: 10.1126/science.1248525.

Neumayer, E. (2013) *Weak Versus Strong Sustainability: Exploring the Limits of Two Opposing Paradigms*. 4th edn. Cheltenham UK & Northampton MA, USA: Edward Elgar Publishing.

Nickell, S. (1981) 'Biases in Dynamic Models with Fixed Effects', *Econometrica*, 49(6), pp. 1417–1426. doi: 10.2307/1911408.

Pacheco, P. (2006) 'Agricultural expansion and deforestation in lowland Bolivia: the import substitution versus the structural adjustment model', *Land Use Policy*, 23(3), pp. 205–225. doi: 10.1016/j.landusepol.2004.09.004.

Pfaff, A. *et al.* (2007) 'Road Investments, Spatial Spillovers, and Deforestation in the Brazilian Amazon*', *Journal of Regional Science*, 47(1), pp. 109–123. doi: 10.1111/j.1467-9787.2007.00502.x.

Pfaff, A. S. P. (1999) 'What Drives Deforestation in the Brazilian Amazon?: Evidence from Satellite and Socioeconomic Data', *Journal of Environmental Economics and Management*, 37(1), pp. 26–43. doi: 10.1006/jeem.1998.1056.

Roodman, D. (2009) 'A Note on the Theme of Too Many Instruments', *Oxford Bulletin of Economics and Statistics*, 71(1), pp. 135–158. doi: 10.1111/j.1468-0084.2008.00542.x.

Rudel, T. K. and Roper, J. (1997) 'The paths to rain forest destruction: Crossnational patterns of tropical deforestation, 1975-1990', *World Development*, 25(1), pp. 53–65. doi: 10.1016/S0305-750X(96)00086-1.

Ruta, G. and Hamilton, K. (2007) '3 - The capital approach to sustainability', in Atkinson, G., Dietz, S., and Neumayer, E. (eds) *Handbook of sustainable development*. Cheltenham UK & Northampton MA: Edward Elgar Publishing, pp. 45–62.

Scott Taylor, M. (2009) 'Innis Lecture: Environmental crises: past, present, and future.', *Canadian Journal of Economics/Revue canadienne d'économique*, 42(4), pp. 1240–1275. doi: 10.1111/j.1540-5982.2009.01545.x.

Sexton, J. O. *et al.* (2016) 'Conservation policy and the measurement of forests', *Nature Climate Change*, 6(2), pp. 192–196. doi: 10.1038/nclimate2816.

Shahbaz, M. *et al.* (2013) 'Does financial development reduce CO2 emissions in Malaysian economy? A time series analysis', *Economic Modelling*, 35, pp. 145–152. doi: 10.1016/j.econmod.2013.06.037.

Solow, R. M. (1974) 'Intergenerational Equity and Exhaustible Resources', *The Review of Economic Studies*, 41, pp. 29–45.

Stern, D. I. (1997) 'Limits to substitution and irreversibility in production and consumption: A neoclassical interpretation of ecological economics', *Ecological Economics*, 21(3), pp. 197–215. doi: 10.1016/S0921-8009(96)00103-6.

Susanti, A. and Maryudi, A. (2016) 'Development narratives, notions of forest crisis, and boom of oil palm plantations in Indonesia', *Forest Policy and Economics*, 73, pp. 130–139. doi: 10.1016/j.forpol.2016.09.009.

the World Bank (2005) *Where is the wealth of nations?: Measuring capital for the 21st century*. Washington D.C.: World Bank Publications. Available at: https://doi.org/10.1596/978-0-8213-6354-6.

Wunder, S. (2001) 'Poverty Alleviation and Tropical Forests—What Scope for Synergies?', *World Development*, 29(11), pp. 1817–1833. doi: 10.1016/S0305-750X(01)00070-5.

6 Appendix

Table 1 about here

Table 2 about here

Tables

Table 1. Descriptive statistics

Variable	Obs	Mean	Std. Dev.	Min	Max	Source	Description
FLoss	595	159,428	425,847	2	3,900,000	Hansen et al, 2013. Data available on-line from: http://earthenginepartners.appspot.com/science-2013-global-forest	Hectares of tree cover loss, by country, from 2001 to 2012 categorized by percent canopy cover, canopy cover > 10%
Exp	595	13.2	4.2	4.3	28.1	WDI-World Bank	General government final consumption expenditure, percentages of GDP
Cred	595	32.4	30.3	0.8	160.1	Idem	Domestic credit provided by the banking sector, percentages of GDP.
GFC	579	23.0	7.91	1.53	58.15	Idem	Gross capital formation, percentages of GDP
GDP per capita	595	2,723	3,808	163	27,029	Idem	GDP per capita, constant 2000 USD
Population	595	7.55e+07	2.24e+08	349,557	1.40e+09	Idem	Population, total
Government stability	595	8.3	1.5	4.6	11.5	International Country Risk Guide (ICRG)	Government stability index from the ICRG database. It both assesses the government's ability to carry out its declared program(s), and its ability to stay in office. Ranks from 0 to 12. An increase means an improvement
Temperature shocks	595	0.53	0.35	0.001	2.79	Climatic Research Unit, University of East Anglia and CERDIhttps://data.cerdi.org/	Deviation of the yearly average of temperatures (°C) from its 1901 to 2012 trend

$Rainfall\ shocks$	595	148.52	197.83	0.03	1,930.8	Climatic Research Unit, University of East Anglia and CERDI https://data.cerdi.org/	Deviation of the yearly average of rainfall levels (mm) from its 1901 to 2012 trend

Descriptive statistics are based on raw data and the most complete specification.

Table 2. List of developing countries included in the dataset

SSA:28	Asia:13	Latin America: 22
Botswana*	Bangladesh	Argentina
Burkina Faso	Brunei Darussalam	Bolivia
Cameroon	China	Brazil
Congo. Dem. Rep.	India	Chile
Congo. Rep.	Indonesia	Colombia
Cote d'Ivoire	Malaysia	Costa Rica
Gabon	Mongolia*	Dominican Republic
The Gambia	Pakistan*	Ecuador
Ghana	Papua New Guinea	El Salvador
Guinea	The Philippines	Guatemala
Guinea-Bissau	Sri Lanka	Guyana
Kenya	Thailand	Haiti
Liberia	Vietnam	Honduras
Madagascar		Jamaica
Malawi		Mexico
Mali		Nicaragua
Mozambique		Panama
Namibia*		Paraguay
Niger*		Peru
Nigeria		Suriname
Senegal		Uruguay
Sierra Leone		Venezuela. RB
South Africa		
Sudan*		
Tanzania		
Togo		
Uganda		
Zimbabwe		

Countries with an * had forest cover which represented less than 5% of their terrestrial surface in 2000.

Table 3. Results on forest cover loss (canopy cover > 10%)

Dependent variable:	$\ln FLoss$			
	1	2	3	4
$\ln FLoss$, lagged	0.870***	0.629***	0.670***	0.637***
	(0.009)	(0.030)	(0.026)	(0.027)
$\ln Exp$	0.010**		0.060**	0.086***
	(0.004)		(0.027)	(0.028)
$\ln Cred$		0.086**	0.079***	0.069*
		(0.034)	(0.028)	(0.036)
$\ln GDP\ per\ capita$	0.055***	0.078***	0.098**	0.068**
	(0.020)	(0.024)	(0.040)	(0.033)
$\ln GDP\ per\ capita$ squared	-0.068***	-0.105***	-0.106***	-0.082***
	(0.023)	(0.030)	(0.040)	(0.027)
$\ln Population$	0.043***	0.048*	0.054**	0.061**
	(0.010)	(0.025)	(0.027)	(0.029)
$\ln Government\ stability$	0.004	0.002	0.000	-0.003
	(0.004)	(0.009)	(0.009)	(0.013)
$\ln\|Temperature\ shocks\|$				-0.097
				(0.067)
$\ln\|Rainfall\ shocks\|$				0.000
				(0.000)
Intercept	-0.003	-0.045**	-0.0430**	0.005
	(0.006)	(0.020)	(0.020)	(0.047)
Number of observations	595	595	595	595
Number of countries	63	63	63	63
Number of instruments	32	24	27	34
EKC:				
Chi2 joint test of significance, p value	0.00	0.00	0.02	0.00
GDP per capita, threshold value	4,266	4,135	4,475	4,298
% countries above the threshold	21.85	23.53	21.85	21.85
Chi2 test $\beta < 1$, p value	0.00	0.00	0.00	0.00
AR(2) test, p value	0.28	0.31	0.28	0.30
Hansen test, p value	0.13	0.27	0.41	0.80

Robust Standard errors in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. GMM-System - Generalized Method of Moments estimator with country fixed effects. The study period is 2001-2012. The lagged Forest Loss is endogenous; Population is strictly exogenous while other variables are considered as weakly exogenous. Chi2 joint test tests that the coefficients of log GDP per capita and log GDP per capita squared are jointly equal to zero.

Table 4. Results on forest cover loss (canopy cover > 10%) – Countries with forest coverage greater above 5% of the surface area

Dependent variable	$\ln FLoss$		
	1	2	3
$\ln FLoss$, lagged	0.534***	0.779***	0.567***
	(0.033)	(0.019)	(0.021)
$\ln Exp$	0.660***		0.139***
	(0.055)		(0.045)
$\ln Cred$		0.095***	0.084**
		(0.020)	(0.039)
$\ln GDP\ per\ capita$	0.434***	0.044**	0.120***
	(0.065)	(0.019)	(0.033)
$\ln GDP\ per\ capita$ squared	-0.436***	-0.065***	-0.134***
	(0.050)	(0.013)	(0.033)
$\ln Population$	0.109**	0.024*	0.060**
	(0.050)	(0.013)	(0.029)
$\ln Government\ stability$	-0.003	0.002	-0.008
	(0.025)	(0.008)	(0.013)
$\ln\|Temperature\ shocks\|$	0.036	0.165***	-0.063
	(0.053)	(0.030)	(0.062)
$\ln\|Rainfall\ shocks\|$	-0.000***	-0.000***	0.000
	(0.000)	(0.000)	(0.000)
Intercept	0.064	-0.078***	-0.015
	(0.068)	(0.021)	(0.044)
Number of observations	535	535	535
Number of countries	57	57	57
Number of instruments	28	35	34
EKC:			
Joint test of significance, p value	0.00	0.00	0.00
Threshold value	4,559	4,756	4,152
% countries above the threshold	22.43	22.43	24.30
Chi2 test $\beta < 1$, p value	0.00	0.00	0.00
AR(2) test, p value	0.36	0.30	0.31
Hansen test, p value	0.15	0.19	0.65

Robust Standard errors in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. GMM-System - Generalized Method of Moments estimator with country fixed effects. The study period is 2001-2012. The lagged Forest is endogenous; Population is strictly exogenous while other variables are considered as weakly exogenous. Chi2 joint test tests that the coefficients of log GDP per capita and log GDP per capita squared are jointly equal to zero.

Table 5. Determinants of forest cover loss with various canopy cover

Dependent variable:	ln $FLoss$					
	>15% canopy cover	>20% canopy cover	>25% canopy cover	>30% canopy cover	>50% canopy cover	>75% canopy cover
	1	2	3	4	5	6
ln $FLoss$, lagged	0.646***	0.647***	0.668***	0.677***	0.670***	0.634***
	(0.025)	(0.025)	(0.023)	(0.024)	(0.020)	(0.022)
ln Exp	0.084***	0.078***	0.080**	0.074***	0.104***	0.070**
	(0.028)	(0.030)	(0.032)	(0.028)	(0.039)	(0.028)
ln $Cred$	0.075**	0.083**	0.085**	0.083**	0.114***	0.189***
	(0.035)	(0.035)	(0.035)	(0.033)	(0.042)	(0.038)
ln $GDP\ per\ capita$	0.069**	0.073**	0.070**	0.062**	0.063**	0.057*
	(0.031)	(0.030)	(0.029)	(0.028)	(0.026)	(0.033)
ln $GDP\ per\ capita$ squared	-0.081***	-0.081***	-0.077***	-0.072***	-0.070***	-0.067**
	(0.026)	(0.025)	(0.024)	(0.023)	(0.024)	(0.028)
ln $Population$	0.056**	0.048*	0.040	0.047*	0.037	0.006
	(0.027)	(0.028)	(0.027)	(0.025)	(0.023)	(0.027)
ln $Government\ stability$	-0.002	-0.005	-0.005	-0.003	0.003	0.022
	(0.012)	(0.011)	(0.010)	(0.011)	(0.010)	(0.017)
ln$\|Temperature\ shocks\|$	-0.081	-0.055	-0.044	-0.063	-0.051	-0.102
	(0.063)	(0.056)	(0.051)	(0.055)	(0.040)	(0.093)
ln$\|Rainfall\ shocks\|$	0.000	0.000	0.000*	0.000	-0.000	-0.000***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Intercept	-0.000	-0.015	-0.018	-0.004	0.004	0.056
	(0.044)	(0.041)	(0.038)	(0.039)	(0.029)	(0.057)
Number of Observations	595	595	595	595	595	595
Number of countries	63	63	63	63	63	63
Number of instruments	34	34	34	34	34	34
EKC:						
Chi2 joint test of significance, p values	0.002	0.003	0.004	0.003	0.007	0.007
Threshold value	4,345	4,446	4,465	4,379	4,443	4,339
% countries above the threshold	21.85	21.85	21.85	21.85	21.85	21.85
Chi2 test $\beta < 1$, p value	0.00	0.00	0.00	0.00	0.00	0.00
AR(2) test, p value	0.30	0.29	0.29	0.29	0.27	0.26
Hansen test, p value	0.78	0.72	0.71	0.72	0.73	0.86

Robust Standard errors in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. GMM-System - Generalized Method of Moments estimator with country fixed effects. The study period is 2001-2012. The lagged Forest is endogenous; Population is strictly exogenous while other variables are considered as weakly exogenous. Chi2 joint test tests that the coefficients of log GDP per capita and log GDP per capita squared are jointly equal to zero.

Table 6. Determinants of forest cover loss using different canopy cover, using an alternative measure of man-made capita

Dependent variable:	$\ln FLoss$	
	1	2
$\ln FLoss$, lagged	0.398***	0.184***
	(0.015)	(0.024)
$\ln GFC$	0.072***	0.129***
	(0.023)	(0.047)
$\ln GDP\ per\ capita$	0.670***	0.667***
	(0.168)	(0.124)
$\ln GDP\ per\ capita$ squared	-0.453***	-0.372***
	(0.115)	(0.091)
$\ln Population$	-0.325	-0.101
	(0.518)	(0.453)
$\ln Government\ stability$	-0.042**	0.035
	(0.021)	(0.028)
$\ln\|Temperature\ shocks\|$		0.110
		(0.114)
$\ln\|Rainfall\ shocks\|$		-0.001***
		(0.000)
Intercept	-0.009	-0.089
	(0.096)	(0.109)
Number of observations	579	579
Number of countries	62	62
Number of instruments	33	30
EKC:		
Chi2 joint test of significance, p value	0.000	0.000
GDP per capita, threshold value	5,630	6,229
% countries above the threshold	17.27	6.91
Chi2 test $\beta < 1$, p value	0.00	0.00
AR(2) test, p value	0.40	0.47
Hansen test, p value	0.60	0.66

Robust Standard errors in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. GMM-System - Generalized Method of Moments estimator with country fixed effects. The study period is 2001-2012. The lagged Forest is endogenous; Population is strictly exogenous while other variables are considered as weakly exogenous. Chi2 joint test tests that the coefficients of log GDP per capita and log GDP per capita squared are jointly equal to zero.

Table 7. Determinants of forest cover loss with various canopy cover using an alternative measure of man-made capita

Dependent variable:	ln $FLoss$					
	>15% canopy cover	>20% canopy cover	>25% canopy cover	>30% canopy cover	>50% canopy cover	>75% canopy cover
	1	2	3	4	5	6
ln $FLoss$, lagged	0.205***	0.164***	0.206***	0.190***	0.257***	0.142***
	(0.024)	(0.018)	(0.017)	(0.017)	(0.016)	(0.009)
ln GFC	0.130***	0.078**	0.074**	0.074**	0.074**	0.047**
	(0.045)	(0.038)	(0.037)	(0.036)	(0.030)	(0.023)
ln GDP per $capita$	0.653***	0.568***	0.548***	0.543***	0.586***	0.625***
	(0.122)	(0.138)	(0.134)	(0.136)	(0.123)	(0.092)
ln GDP per $capita$ squared	-0.369***	-0.297***	-0.288***	-0.285***	-0.314***	-0.359***
	(0.090)	(0.101)	(0.098)	(0.099)	(0.094)	(0.077)
ln $Population$	-0.095	0.058	0.026	-0.019	0.042	-0.080
	(0.431)	(0.358)	(0.342)	(0.333)	(0.283)	(0.160)
ln $Government$ $stability$	0.041	0.002	0.003	0.003	0.011	0.019
	(0.027)	(0.023)	(0.023)	(0.022)	(0.021)	(0.015)
ln$\|Temperature\ shocks\|$	-0.001***	-0.000***	-0.000***	-0.000***	-0.001***	-0.000***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
ln$\|Rainfall\ shocks\|$	0.098	0.166**	0.145*	0.149*	0.199**	0.192***
	(0.111)	(0.085)	(0.081)	(0.078)	(0.079)	(0.057)
Intercept	-0.077	-0.097	-0.091	-0.103	-0.080	-0.118**
	(0.105)	(0.095)	(0.091)	(0.090)	(0.081)	(0.056)
Number of Observations	579	579	579	579	579	579
Number of countries	62	62	62	62	62	62
Number of instruments	30	31	31	31	31	31
EKC:						
Chi2 joint test of significance, p values	0.00	0.00	0.00	0.00	0.00	0.00
Threshold value	6,190	6,461	6,447	6,453	6,370	6,130
% countries above the threshold	6.91	6.91	6.91	6.91	6.91	8.64
Chi2 test $\beta < 1$, p value	0.00	0.00	0.00	0.00	0.00	0.00
AR(2) test, p value	0.45	0.38	0.36	0.37	0.33	0.31
Hansen test, p value	0.59	0.82	0.84	0.84	0.77	0.79

Robust Standard errors in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. GMM-System - Generalized Method of Moments estimator with country fixed effects. The study period is 2001-2012. The lagged Forest is endogenous; Population is strictly exogenous while other variables are considered as weakly exogenous. Chi2 joint test tests that the coefficients of log GDP per capita and log GDP per capita squared are jointly equal to zero.

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