Disinflation against the Environment? An application to the trade-off between seigniorage and deforestation

Jean-Louis Combes, Pascale Combes Motel, Alexandru Minea, Patrick Villieu

Document de travail de la série

Etudes et Documents

E 2010.14

Disinflation against the Environment?

An application to the trade-off between seigniorage and deforestation

J.-L. Combes[&], P. Combes-Motel[#], A. Minea[@] and P. Villieu[ϒ]

mai 2010

[&] CERDI (University of Auvergne), 65 Boulevard François Mitterrand, B.P. 320, 63009 Clermont-Ferrand Cedex 1, France. *E-mail:* j-l.combes@u-clermont1.fr.

[#] CERDI (University of Auvergne), 65 Boulevard François Mitterrand, B.P. 320, 63009 Clermont-Ferrand Cedex 1, France. *E-mail:* p.motel_combes@u-clermont1.fr.

[@] *Corresponding author*: CERDI (University of Auvergne), 65 Boulevard François Mitterrand, B.P. 320, 63009 Clermont-Ferrand Cedex 1, France. *E-mail:* alexandru.minea@u-clermont1.fr.

Webpage: http://minea.alexandru.googlepages.com/

[ϒ] LEO (University of Orléans), Faculté de Droit, d'Economie et de Gestion, Rue de Blois, B.P. 6739, 45067 Orléans Cedex 2, France. *E-mail:* patrick.villieu@univ-orleans.fr.

P. Combes-Motel acknowledges financial support from the French Ministry of Research grant ACI "Macroeconomic Policies and Deforestation in Developing Countries". This project benefited among others from the contribution of J-L. Arcand, S. Guillaumont-Jeanneney and P. Guillaumont. Usual disclaimers apply.

Abstract: The forest still covers an important share of land area in many developing countries and represents an important source of revenue for governments. Another major contribution to government revenues comes from printing money, namely the seigniorage. Building on a simple theoretical model where governments target inflation and aim at reducing deforestation while minimising a welfare loss function, we exhibit the potential substitution effect between seigniorage and deforestation revenues. Regressions run on a panel of developing countries show that there exists a non-negligible substitution effect between seigniorage and deforestation revenues, which is, as suggested by the theoretical model, even stronger if the endogenous character of seigniorage is taken into account. Adding variables suggested by the theoretical model as well as usual control variables in deforestation equations, do not alter the main result. As a consequence, disinflation policies as recommended by the IMF, may hasten deforestation. The model is extended to address this problem, which shows that international transfers dedicated to rainforest protection may upturn the positive correlation between tighter monetary policies and deforestation and give some additional support to REDD's advocates.

Keywords: deforestation, seigniorage, inflation, developing countries, panel data analysis.

JEL codes: O13, Q23, E42, E52

Disinflation against the Environment?

An application to the trade-off between seigniorage and deforestation

The Copenhagen talks on climate change showed that participants at least agreed on the need to “slow, halt and eventually reverse” deforestation in developing countries. Six developed countries have pledged substantial amounts to fund a program to curb deforestation, which is considered as a substantial issuer of GHG. This appears to be a noticeable result since forests were dropped out the Kyoto Protocol because countries like Brazil were defending their sovereignty over their forests. Campaigns by environmental groups have managed to put a greater concern on forest contribution to climate change mitigation.[1] Those environmental objectives are not only important in their own right; they also contribute to the achievement of economic development as stated in the Millennium Development Goals. These facts are probably not disconnected with respect to the expansion of the literature analyzing sustainable development issues in the last two decades (e.g. López & Toman, 2006).

Recent data show that deforestation occurs since 1990 at a yearly pace of more than 8 million hectares per year (see *Table 1* and *Appendix A*). If Europe and North-America preserve their forest stock, developing countries areas (and in particular Africa and Central & South America) are most affected by deforestation. Forests cover in 2005 about 30% of the world land area, and close to one half of some regions of the world (46.2% in Central & South America, 44% in Western & Central Africa).

[1] The newly elected US President agenda makes reference to Al Gore’s 2000 report conclusions about global environment problems. Several political analysts do not exclude a cause-effect between the projection of the film “Home” (dealing with environment imbalances all over the world) and the increased number of seats of “Green” parties following the 2009 European Union Parliament elections.

Table 1 - Extent of and change in forested areas by geographic areas, 1990-2005

	Areas		*Change rate*		*Yearly (average) Change rate*	
	1990	*2005*	*1990-2005*		*1990-2005*	
	1000 ha	*1000 ha*	*1000 ha*	*%*	*1000 ha*	*%*
Europe	989 320	1 001 394	12 074	1.22%	805	+0.08%
North America	677 801	677 464	-337	-0.05%	-22	0.00%
Asia	574 487	571 577	-2 910	-0.51%	-194	-0.03%
Oceania	212 514	206 254	-6 260	-2.95%	-417	-0.20%
Central & South America	923 807	859 925	-63 882	-6.92%	-4 259	-0.46%
Africa	699 361	635 412	-63 949	-9.14%	-4 263	-0.61%
World	4 077 291	3 952 025	-125 266	-3.07%	-8 351	-0.20%

Source: FAO, Global Forest Resources Assessment 2005 (http://www.fao.org/forestry/32033/en/)

Table 2 - The importance of forestry in GDP, trade and fiscal revenues, 1998-2005

Region	*Percentages of GDP*	*Percentages of trade*	*Percentages of fiscal revenues*
Asia	0.9	1.3	5.1
Latin America & Caribbean	2.2	3.3	11.2
Sub-Saharan Africa	2.3	1.6	11.1

Source: Authors' calculation from FAO and WBI databases

Table 2 shows that forest products generate non negligible revenues for Sub-Saharan African and Latin American countries. Moreover, recall that these figures are highly underestimating the real impact of forests, since it widely recognized that, because of missing markets and/or the public character of forest services, the economic importance of forests is understated particularly in developing countries (FAO, 1997).[2]

Although they still fall short with respect to the weight of oil revenues (for example, oil taxes account in 2008 for about one half (Nigeria or Venezuela) and up to 75% (Angola) of Government receipts), deforestation revenues may still represent an important share of Government resources. For example, in Central and West African countries, where forests have been often granted to concessionaires since the colonial era, these revenues remain high. According to evidence from Karsenty (2007), forest taxes are about 18-19% (Cameroon and Gabon) and close to one third (Congo Republic) of Government resources. Finally, one should notice that in countries with a very important forest sector, their contribution to the

[2] The report by Saunders, Ebeling & Nussbaum (2008) estimates that in 1997 in Brazil only 40% of wood production was legal, and thus subjected to Government taxation. The authors also recall that, during the last decade, lost revenues from undeclared forest activity are as high as 15 billion US dollars per year.

Government budget may even overpass the one from other natural resources (for example, in Indonesia forest taxes represent 27% of fiscal revenues in 2008, six points more than oil taxes).

In addition to forest resources, Governments of developing countries also build their revenues on seigniorage, which are the revenues generated by the newly issued money and measured (as usual) as the changes in the reserve money over GDP. If we consider averages over the 1970-2005 period, the weight of seigniorage is between 1 and 10% on regional averages of Government revenues (*Table 3*), but may climb up to one third or even one half, especially in Latin America countries (Argentina or Brazil, among others). These figures (see also *Appendix C*) support the fact that seigniorage may represent an important share of government revenues in developing countries, as previously acknowledged both empirically (e.g. Cukierman, Edwards & Tabellini, 1992) and theoretically (e.g. Minea & Villieu, 2009). Revenues generated by forests and money thus constitute an important source of government revenues in a number of emerging and developing countries, with limited ability to levy taxes and limited access to international debt markets. Furthermore, these revenues are probably the hardest forms of taxation to evade and their political cost may be lower than other forms of fiscal policy. It is also worth to notice that seigniorage revenues have decreased in the nineties as the result of disinflation policies promoted by the International Monetary Fund.

Table 3 - The importance of seigniorage revenues in GDP, 1970-2005, in percentages

Region	*1970-2005*	*1970-1979*	*1980-1989*	*1990-1997*	*1998-2005*
Asia	1.4 (3.5)	1.3 (0.4)	1.4 (10.3)	1.6 (8.3)	1.1 (1.0)
Latin America & Caribbean	10.6 (3.1)	2.1 (0.4)	27.1 (9.2)	13.2 (8.0)	0.6 (1.0)
Sub-Saharan Africa	4.0 (2.4)	0.9 (0.3)	1.1 (6.9)	11.3 (5.8)	1.9 (0.7)

Standard errors in parentheses

Given their importance as financing sources for Governments in developing countries, we try in this paper to evaluate the link between deforestation which can be more generally considered as a proxy for environment goals and seigniorage. This issue does not seem to have been much examined in the literature which has mainly focused on the indirect link between fiscal and monetary policies and environmental quality. Faria (1998) investigates whether fiscal and monetary policies have environmental effects, with a particular emphasis on the environmental impact of inflation. In his model, economic growth negatively affects the environment; if the anti-Tobin effect dominates, inflation may become “environmentally friendly”. Many other studies have analyzed the effect of structural adjustment programs on the environment (*i.e.*, Munasinghe, 1999; Strand and Mundaca, 2006), but with few references to the inflation-versus-environment trade-off. We examine the possible conflict between disinflation policies and natural resources depletion like deforestation. Therefore, we can wonder about a possible substitution effect between these two variables: disinflation policies could lead governments to search other fiscal resources on the form of increased taxes on the natural resource sector. Thus, inflation-fighting policies, such as recommended by stabilization and structural adjustment programs, could cause an over-depletion of natural resources with harmful consequences on environmental quality and possible international spillover effects.

We first present a simple theoretical model built on this intuition (Section 1). Second the econometric on a panel of developing countries supports our theoretical conclusions, namely that lower seigniorage revenues lead to a higher deforestation rate (Section 2). This result is robust to different control variables, including an environmental Kuznets curve, different fiscal policy variables, population, mineral resources or prices (the exchange rate) or when accounting for the endogeneity between seigniorage and deforestation using instrumental variables. Third, a solution to the trade-off between disinflation and environment is searched (Section 3). An "optimal" contract, imposing some environmental rewards, could circumvent the problem of substitutability between the two objectives and constitute a possible solution so that inflation-fighting policies would no longer be detrimental to deforestation.

1. A theoretical model of substitution between forest and seigniorage revenues

We consider a theoretical model based on Barro & Gordon (1983) setup. We suppose that the log of output y positively depends on inflation surprises $(\pi - \pi^e)$, with π the inflation rate and π^e the anticipated inflation rate, and on the log of public spending g, with α and β strictly positive weights:

$$y = \alpha(\pi - \pi^e) + \beta g \quad (1)$$

We suppose the presence of a single Monetary and Fiscal Authority (to simplify, we denote this consolidated Authority by "Government")[3] that may finance public spending g by the means of revenues from natural resources f and inflation π (seigniorage revenues).[4] In the following we assume that f stands for revenues from deforestation, but our analysis would still hold if we consider other types of natural resources (for example, oil or mineral resources). We also introduce a parameter for the quality of institutions $\phi \in [0;1]$, to capture the fact that better institutions improve the collection of forest revenues and reduce deforestation (at given g and π):

$$g = \phi f + \pi \tag{2}$$

We consider that the Government maximizes the following welfare function:

$$L^g = -\frac{1}{2}\left\{(\pi - \bar{\pi})^2 + \lambda\left[\alpha(\pi - \pi^e) + \beta(\phi f + \pi)\right]^2 + \mu\left(f - \bar{f}\right)^2\right\} \tag{3}$$

According to (3), the Government's welfare functions depends on three objectives. First, on inflation deviations with respect to its targeted value $\bar{\pi}$. Remark that, according to IMF's classification, 31 out of the countries included in our sample of developing countries were having explicit or implicit monetary targets in 2006 (IMF, 2006). Second, the welfare function also depends on output deviations with respect to a targeted (long-term) value, which we normalize for simplicity to zero.

Third, allowing for a deforestation goal in the welfare function is motivated by the increase of the importance of sustainable development in both people's conscience and politics' preoccupations (as stated in *Introduction*, see footnote 1). Therefore, in countries with an important forest, Government may well be interested in preserving the forest by imposing a "natural" rate of deforestation $\bar{f}$ and penalizing any deviation from this rate. $\bar{f}$ may be either settled by the Government, or be imposed by a supra authority. In both cases, we suppose that $\bar{f}$ is settled optimally, as the sustainable depletion rate for an

[3] The presence of a single authority is compatible with the fact that seigniorage revenues are available at no transfer cost.

[4] As mentioned in *Introduction*, we disregard taxes and public debt financing. One may also consider g as the public spending that cannot be financed by tax and public debt revenues.

exhaustible/renewable resource.[5] Strictly positive parameters λ and μ capture the relative weights of output and deforestation objectives in the Government welfare function.

Since L^g is convex in its arguments, we find the optimal (that maximize L^g) inflation and deforestation values using the first order conditions (remark that, in the absence of stochastic shocks, $\pi = \pi^e$ ex-post):

$$/\pi: \quad (\pi - \bar{\pi}) + \lambda(\alpha + \beta)\beta(\phi f + \pi) = 0 \tag{4a}$$

$$/f: \quad -\lambda\phi\beta^2(\phi f + \pi) - \mu(f - \bar{f}) = 0 \tag{4b}$$

Using (4a) and (4b) we can see that inflation and deforestation are jointly determined in our model:

$$\pi = \frac{\bar{\pi} - \lambda\beta\phi(\alpha + \beta)f}{1 + \lambda\beta(\alpha + \beta)} \text{ and } f = \frac{\mu\bar{f} - \lambda\beta^2\phi\pi}{\mu + \lambda\beta^2\phi^2} \tag{5}$$

Finally, defining $A \equiv 1 + \lambda\beta(\alpha + \beta)$, the equilibrium optimal values for inflation and deforestation are:

$$f^* = \frac{\mu A\bar{f} - \lambda\phi\beta^2\bar{\pi}}{\lambda\phi^2\beta^2 + \mu A} \tag{6a}$$

$$\pi^* = \frac{\bar{\pi}(\lambda\phi^2\beta^2 + \mu) - \lambda\beta\phi\mu(\alpha + \beta)\bar{f}}{\lambda\phi^2\beta^2 + \mu A} \tag{6b}$$

The following *Proposition* establishes the key results of our model.

Proposition:

a) a tighter monetary policy (a lower inflation target $\bar{\pi}$) decreases the optimal inflation rate (π^*) but increases the deforestation rate (f^*);

b) a lower deforestation target $\bar{f}$ decreases the deforestation rate (and increases the optimal increases the inflation rate);

c) the quality of institutions ϕ has a negative impact on the deforestation rate (f^*).

[5] The question of the renewable/exhaustible character of equatorial and tropical forests is still an open question.

Proof:

a) Using simple derivatives we find that a tighter monetary policy (i.e. a lower inflation target $\bar{\pi}$) decreases as expected the optimal inflation rate ($\frac{d\pi^*}{d\bar{\pi}} = \frac{\lambda\phi^2\beta^2 + \mu}{\lambda\phi^2\beta^2 + \mu A} > 0$), but increases the deforestation rate ($\frac{df}{d\bar{\pi}} = -\frac{\lambda\phi\beta^2}{\lambda\phi^2\beta^2 + \mu A} < 0$). Consequently, there exists a trade-off between macroeconomic objectives (inflation) and environment objectives (deforestation): monetary policies that aim at reducing inflation are found to worsen the environment, by increasing the depletion rate of natural resources (for example, in our model, the deforestation rate).

Our result may be used to analyze the effects engendered by the action of international institutions fighting inflation (for example, the IMF). Implementing policies that aim at lowering the inflation generates a resource loss, in the form of lower seigniorage revenues. Consequently, imposing low inflation rates may lead to a higher natural resources depletion rate (monetary revenues and natural resources revenues are substitutes).

b) The deforestation target has opposite effects on the two objectives: imposing a lower deforestation target decreases the optimal deforestation rate ($\frac{df^*}{d\bar{f}} = \mu A > 0$) and increases optimal inflation ($\frac{d\pi^*}{d\bar{f}} = -\frac{\lambda\beta\phi\mu(\alpha + \beta)}{\lambda\phi^2\beta^2 + \mu A} < 0$). The raise in optimal inflation reflects the fact that more seigniorage revenues are needed to offset the reduction in deforestation resources. Typically, this is the case when forest protection organizations exert some form of pressure over domestic institutions to make them lower forest depletion. In this case the forest is better preserved, but seigniorage must raise. This result confirms the trade-off between environmental goals and macroeconomic stability.

c) The quality of institutions has a negative impact on the deforestation rate: when the quality of institutions is higher, Authorities are able to collect a higher share of (given) deforestation revenues. As a result, optimal deforestation rate may be decreased. Consequently, there exists a negative link between the quality of institutions and the deforestation rate ($\frac{df^*}{d\phi} < 0$).

Finally, remark that the substitution effect between monetary policy and environment goals holds when controlling for public spending. Assuming, as Alesina & Tabellini (1987), that Government targets a strictly positive public spending value $\bar{g}$, the Government welfare function and equilibrium inflation and deforestation rate become (with $\beta = 0$ for simplicity):

$$L^g = -\frac{1}{2}\left\{(\pi - \bar{\pi})^2 + \lambda\left[\alpha(\pi - \pi^e)\right]^2 + \mu\left(f - \bar{f}\right)^2 + \varepsilon(g - \bar{g})^2\right\} \quad (7)$$

$$f^* = \frac{(1+\varepsilon)\mu\bar{f} + \varepsilon\phi\bar{g} - \varepsilon\phi\bar{\pi}}{\mu + \mu\varepsilon + \varepsilon\phi^2} \quad (8a)$$

$$\pi^* = \frac{\left(\mu + \varepsilon\phi^2\right)\bar{\pi} + \varepsilon\mu\bar{g} - \varepsilon\phi\mu\bar{f}}{\mu + \mu\varepsilon + \varepsilon\phi^2} \quad (8b)$$

If the Government targets a higher amount of public spending $\bar{g}$, both inflation and deforestation are higher in equilibrium. Previous results are unchanged, since a tighter monetary policy (a lower inflation target $\bar{\pi}$) increases the equilibrium deforestation rate (f^*).

The next section explores our theoretical conclusions by proposing an econometric analysis on a panel of developing countries with important forests.

2. Empirical evidence of the existence of a substitution effect between deforestation and seigniorage

According to our theoretical model, there exists a substitution effect between seigniorage and deforestation (and, more generally, natural resources depletion). This section tests this result on a panel of developing countries with important forests (at least 10% of forest area in total surface). This section includes the basic econometric specification, the data set and presents the econometric results.

2.1 Basic econometric specification

The panel data model with fixed effects is considered since the Hausman test rejects the null hypothesis of no correlation between specific effects and the regressors :

$$Defor_{it} = a_i + a_t + b_0 Seigniorage_{it} + \sum_{k=1}^{K} b_k x_{k;it} + \varepsilon_{it} \tag{9}$$

$Defor_{it}$ is the average deforestation rate, with subscript $i = \overline{1,N}$ designating countries and subscript $t = \overline{1,T}$ standing for the time period. a_i is the intercept term for country i, a_t stands for the fixed effect for period t and ε_{it} is an error term that is normally and independently distributed. a_i's capture unobservable countries' structural characteristics that are period invariant (for example, long term climatic and geographical characteristics), while a_t's retrieve unobservable periods' characteristics that are country invariant (for example, international price movements). Coefficient b_0 measures the marginal effect of seigniorage, while b_k, $k = \overline{1,K}$ are the coefficients to be estimated for the K control variables.

We consider several control variables x_k, which are either assumed from the theoretical model or inferred from studies on the determinants of deforestation. Concerning the first group of control variables, our theoretical model predicts that better institutions may enhance the forest protection. Using two different databases, we select two measures for the quality of institutions, namely ratings from Economic Freedom of the World (*Civil*) or from the Freedom House (*Fraser*). Another feature of the theoretical model is that an increase in public spending is detrimental to the forest, since public spending enhance the need for additional resources (including seigniorage revenues). We reproduce this effect by using the ratio of general government consumption to GDP (*Gratioy*). The ratio of the total debt service to exports (*DebtBurden*) is also introduced following Kahn & McDonald (1995) who stress the significant positive association between public debt and deforestation in LDCs. These authors defend debt alleviations as a mean to reduce the pressure to deforest and suggest that "win-win policies" like debt-for-nature swaps are feasible, in order to reduce both public debt and natural resources depletion.

The second group of control variables is inspired by the adjacent literature on deforestation. First, we aim at reproducing the existence of an Environmental Kuznets Curve (EKC for deforestation), as emphasized by several recent contributions.[6] To this end, we allow for a non linear influence of per-capita income (*GDPPC*) on deforestation, using a quadratic form through the term *Squared GDPPC*. Second, there is no clear-cut established effect of the population size on deforestation. On the one hand, it can reduce deforestation by enhancing the demand for forest products (Foster & Rosenzweig, 2003). On the other hand, population pressure may accelerate the conversion of forest into arable lands and may increase the demand for fuel wood (Cropper and Griffiths, 1994). We propose two measures of population, as either total population (*Poptot*) or as urban population in percentage of total population (*Urbpop*). Third, we wish to investigate if the negative impact of seigniorage on deforestation still holds when controlling for government revenues generated by other natural resources depletion, such as mineral depletion (*Mineral*) or fuel exports revenues (*XFuel*). Fourth, the real exchange rate (*Reer*) is introduced to control for the competitiveness of the export sector (we expect that a real appreciation preserves the forest, see Arcand et al., 2008). Finally, we test for an effect of economic growth (*Growth*) on deforestation.

2.2 The data

For each of the 74 countries to be potentially included in the sample (for the list of countries see *Appendix B*), four observations are available for the following periods: 1970-1979 (*period1*), 1980-1989 (*period2*), 1990-1997 (*period3*) and 1998-2005 (*period4*). The use of period averages allows reducing short-term fluctuations. We define deforestation (*Defor*) as the average deforestation rate over the considered period. Concerning the seigniorage, we follow Aisen & Vega (2008) and define it as the revenue generated from the issuance of

[6] See, among others, Angelsen & Kaimowitz (2000), Koop & Tole (2001), Barbier (2004), Bhattarai & Hammig (2004) or Culas (2007).

reserve money: *seigniorage* captures the change in reserve money over GDP. *Appendix 1* reports data definitions and sources for the remaining variables.

2.3 Econometric results

C1. The main results

In equation [1] (*Table 4* below) we measure the influence of seigniorage on deforestation while controlling for a set of six "basic" variables: three from the theoretical model (the quality of institutions and fiscal variables – public consumption and the debt burden, and three on the basis of other studies on the drivers of deforestation (the EKC, population size, and economic growth).

Remark first that control variables are significant and have the expected sign. According to our theoretical model, better institutional quality lowers deforestation. This result is close to evidence from Bhattarai & Hammig (2004), who highlight a positive effect of an improvement in political institutions and governance, measured with indexes of political rights and/or civil liberty, for forest preservation. Concerning the other feature of our theoretical model, both public spending and the debt burden exert a positive effect on deforestation. Population shifts upwards the relationship between deforestation and income. As debated in the literature, economic growth has an ambiguous impact on deforestation, since it may either exacerbate it (when primarily driven by the agricultural sector which competes for forested lands) or slow down forest depletion (when economic growth mirrors structural changes in the economy taking place in the manufactured or services sectors). The negative significant coefficient of variable *Growth* suggests the latter correlation.

Finally and most important, when accounting for all these control variables, we may clearly isolate a negative and significant link between seigniorage and deforestation in regression [1], in line with our theoretical conclusions.

However, an immediate critique for the quality of our results concerns the assumption of orthogonality between seigniorage and deforestation. Indeed, this assumption may be violated on two grounds. First, the seigniorage variable may be measured with an error (the attenuation bias). Second, one may question the absence of endogeneity between seigniorage and deforestation presumed in regression [1]; or to put it differently, regression [1] might reproduce an effect from equation (5) (namely $\partial f / \partial \pi$), while we rather aim at testing an effect from equation (6a) (namely $\partial f / \partial \overline{\pi}$). To deal with these problems, we draw on the

Instrumental Variables (IV) technique and the panel two stage least squares (PTSLS) estimation method. [7]

We split IV into two groups. First, we use the lagged seigniorage *Seigniorage*(-1) under the hypotheses that seigniorage encompasses some inertia and that unobservable determinants of deforestation are independent over long lasting periods. In the second group we include ratings of Central Banks (CB) independence (*CBIndep* and *CBturnover*, see *Appendix 1* for their definition), which obviously have no direct influence on deforestation and decrease seigniorage.

Thus, contrary to regression [1] estimated by the PLS (Panel Least Squares) technique, the remaining regressions in *Table 4* (regression [2]-[5]) are estimated using the PTSLS method.

[7] To put it differently, equation [1] measures $\partial f / \partial \pi$. However, we want to measure $\partial f / \partial \overline{\pi}$, that we can write as $\frac{\partial f}{\partial \pi}\frac{\partial \pi}{\partial \overline{\pi}}$. The use of instruments (first stage) allows measuring $\partial \pi / \partial \overline{\pi}$ and plugging this into the second stage (equations [2]-[5]) yields the elasticity $\partial f / \partial \overline{\pi}$.

Table 4 - Estimation results (regressions [1]-[5])

Dependent variable: Defor

	[1]	[2]	[3]	[4]	[5]
Seigniorage	-0.006	-0.010	-0.008	-0.012	-0.033
	(-1.966)***	(-1.825)**	(-2.628)****	(-2.000)***	(-4.941)****
Institutions Fraser	-0.001	-0.001	-5.2E-4	-8.9E-4	-0.004
	(-2.012)***	(-2.194)***	(-1.105)	(-2.929)***	(-3.934)****
Gratioy	0.015	0.019	0.021	0.025	0.049
	(1.798)**	(1.842)**	(1.824)**	(1.851)**	(4.047)****
DebtBurden	0.010	0.010	0.005	0.009	0.008
	(3.198)****	(3.532)****	(9.491)****	(6.902)****	(2.453)***
Log(Poptot)	0.016	0.018	0.028	0.028	0.024
	(1.624)**	(1.844)**	(1.945)**	(1.811)**	(2.268)***
Log(Gdppc)	0.003	0.017	0.033	0.024	-4.0E-4
	(0.635)	(1.405)	(2.522)***	(1.599)*	(-0.030)
Log(Gdppc) squared	-0.001	-0.001	-0.002	-0.002	-1.8E-4
	(-2.134)***	(-1.943)***	(-2.805)****	(-1.985)***	(-0.178)
Growth	-2.3E-4	-2.8E-4	-3.4E-4	-2.7E-4	-3.6E-4
	(-2.746)****	(-2.933)****	(-2.389)***	(-2.481)***	(-3.540)****
Method of estimation	PLS	PTSLS	PTSLS	PTSLS	PTSLS
Adj R2	0.42	0.44	0.45	0.50	0.27
Nb of obs	130	125	89	111	122

PLS: Panel Least Squares with countries and periods fixed effects; PTSLS: Panel Two-Stage Least Squares with countries and periods fixed effects. First stage identifying instruments are reported in *Table 5*. t-statistics in parentheses are robust to cross-section heteroskedasticity in the disturbances. **** significant at the 1% level; *** significant at the 5% level; ** significant at the 10% level; * significant at the 15% level

Table 5 below depicts the results of the first stage equations that allow computing the exogenous (not correlated to deforestation) part of seigniorage using different combinations of instruments.

Table 5 - First stage regressions (regressions [2]-[5])

Dependent variable : Seigniorage

First stage equations	[2]	[3]	[4]	[5]
Seigniorage(-1)	0.332	0.223	0.307	
	(7.120)****	(2.642)***	(6.426)****	
CBturnover		0.304	0.207	0.200
		(4.814)****	(4.739)****	(6.640)****
CBindep		-0.287		
		(4.715)****		
Adj R2	0.726	0.815	0.749	0.631

PLS estimations with robust t reported in brackets. Exogenous control variables coefficients and t statistics are not reproduced. **** significant at the 1% level; *** significant at the 5% level; ** significant at the 10% level; * significant at the 15% level

Table 6 below details results by proposing several tests of the quality of the adjustment of regressions in the first stage. The over-identification Sargan test (Sargan, 1988) checks the exogeneity of the instruments, while the partial Shea-Godfrey R^2 (Godfrey, 1999) and the F test of excluded instruments (Stock, Wright & Yogo, 2002) provide information that allows detecting weak instruments.

Table 6 - Restriction tests (regressions [1]-[5])

Dependent variable : Seigniorage

		[1]	[2]	[3]	[4]	[5]
Instruments List			I	II	III	IV
Sargan Test	p-Value			0.971	0.999	
First stage: Shea-Godfrey statistic	Partial R^2		0.342	0.892	0.245	0.299
First stage: Stock-Yogo statistic	Partial F		30.015	8.892	14.372	2.818

Instruments. List I: seigniorage(-1); List II: seigniorage(-1), CBindep, CBturnover; List III: seigniorage(-1), CBturnover; List IV: CBturnover.

These tests support our instrumentation strategy and the pertinence of the instruments. According to Stock, Wright & Yogo (2002, p.522) at least PTSLS regressions [2] and [4] are reliable, since the first stage F statistics are sufficiently large with respect to their criterion, namely superior to 10. Nevertheless, in all cases, the partial R^2, which measures the instrument relevance, is satisfactory. Moreover, the Sargan test does not reject the null hypothesis of the over-identification restrictions.

Regressions [2]-[5] in *Table 5* present our main estimation results (or the second stage of the PTSLS). With respect to equation [1], accounting for the endogeneity between seigniorage and deforestation has no effect on the significance or the sign of the control variables (in particular, results concerning EKC are improved). However, what is more important is that the coefficient of the variable *Seigniorage* measures this time the impact of the monetary policy variables on deforestation (namely $\partial f / \partial \pi$). Remark first that the "exogenous" part of seigniorage still has a negative and significant impact on the deforestation, thus the two resources are substitutes, as in our theoretical model. Second, the absolute value of the seigniorage coefficient is higher, i.e. the substitution effect between seigniorage and deforestation is enforced when focusing on the exogenous component of seigniorage.[8]

[8] Hence, the PLS estimation of the seigniorage coefficient is biased towards 0 for two reasons: the attenuation bias and the positive correlation between seigniorage and the unobserved determinants of deforestation, i.e. a

C2. Robustness tests

The purpose of this sub-section is to explore the robustness of our main results in different directions. The estimation results for the robustness equations [6]-[12] are detailed in *Table 7*, while *Table 8* presents the corresponding instruments relevance tests (all equations are estimated using the PSTLS technique) and *Table 8* weak instruments tests. We split our robustness tests in two groups.

Group 1: different measures for control variables and *subsequent control variables*

First, beside total population (*Poptot*), we introduce a second measure, namely urban population relative to total population (*Urbpop*). Results in regressions [6]-[8] and [10]-[12] support that urban population has a positive and significant influence on deforestation, as expected. Second, replacing the institutional quality variable (*Fraser*) used in regressions [1]-[7] and [9] with an alternative measure (*Civil*) does not change results in regression [8]: better institutions still allow preserving the forest.

Third, we introduce in equation [9] two variables accounting for other natural resources depletion. Both mineral depletion (*Mineral*) and fuel exports (*Xfuel*) have a negative and significant impact on deforestation, thus reproducing a substitution effect between forest revenues and other natural resources revenues.[9] Finally, the initial forest area does not seem to have a significant effect on deforestation (according to regression [7]); thus, our econometric results invalidate the existence of a convergence effect of forests towards a long-term level.

country facing institutional, political or economic failures will draw on seigniorage revenues and poorly manage its natural resources as well.

[9] To put it differently, since these natural resources are traded-off with the forest, their use is expected to protect the forest. This is not to be interpreted as an incentive to extract more minerals and fuels, but, on the contrary, as a future negative effect on the forest area as soon as these resources will become scarce/expensive.

Table 7 - Estimations Results (regressions [6]-[12])

Dependent variable: Defor

	[6]	[7]	[8]	[9]	[10]	[11]	[12]
Seigniorage	-0.011	-0.011	-0.009	-0.028	-0.028	-0.010	-0.009
Level	(-2.010)***	(-2.049)***	(-1.780)**	(-2.625)****	(-2.576)****	(-2.096)***	(-2.170)***
Squared						0.004	
						(3.409)****	
Institutions	-8.7E-4	-7.7E-4		-0.003	-0.003		-7.7E-4
Fraser	(-2.164)***	(2.725)****		(-3.021)****	(-2.441)****		(-1.782)**
Civil			-0.001			-9.0E-4	
			(-1.752)**			(-1.070)	
Gratioy	0.023	0.024	0.024	0.063	0.065	0.011	0.030
	(1.832)**	(1.857)**	(1.629)*	(2.633)****	(2.806)****	(1.190)	(2.177)***
DebtBurden	0.008	0.008	0.005	0.011	0.009	0.007	0.007
	(5.046)****	(5.528)****	(2.258)***	(2.865)****	(2.858)***	(12.199)****	(3.140)****
Log(Poptot)	0.023	0.024	0.029	0.034	0.027	0.023	0.016
	(1.786)**	(1.807)**	(1.687)**	(1.790)**	(1.697)**	(1.289)	(1.318)
Urbpop	0.021	0.021	0.028		0.030	0.017	0.020
	(2.787)****	(2.805)****	(2.545)***		(1.151)	(8.131)****	(4.116)****
Log(Gdppc)	0.030	0.029	0.044	0.042	0.042	0.012	0.025
	(1.533)*	(1.517)*	(2.668)***	(3.171)****	(2.351)***	(1.686)**	(1.557)****
Log(Gdppc)	-0.002	-0.002	-0.003	-0.003	-0.003	-0.001	-0.002
squared	(-1.860)**	(-1.844)**	(-2.790)****	(-4.578)****	(-3.047)****	(-2.585)***	(-1.931)****
Growth	-2.2E-4	-2.4E-4	-3.3E-4	-2.3E-4	-2.2E-4	-1.9E-4	-1.5E-4
	(-1.853)**	(-2.739)****	(-2.020)***	(-3.643)****	(-2.061)***	(-3.226)****	(-1.796)**
Log(foret0		8.8E-4					
		(0.505)					
XFuel				-0.019	-0.017		
				(-2.931)****	(-2.717)****		
Mineral				-0.086	-0.108		
				(-6.648)****	(-5.322)****		
Reer					-2.0E-5		-2.3E-5
					(-2.948)****		(-5.456)****
Reerins							7.5E-5
							(1.342)
Aidgni							-0.025
							(-2.684)****
Method of estimation	PTSLS	PTSLS	PTSLS	PTSLS	PTSLS	PTSLS	PTSLS
Adj R2	0.50	0.50	0.48	0.47	0.50	0.50	0.51
Nb of obs	111	111	89	103	103	121	110

PLS: Panel Least Squares with countries and periods fixed effects; PTSLS: Panel Two-Stage Least Squares with countries and periods fixed effects. First stage identifying instruments are reported in *Table 7*. *t* statistics in brackets are robust to cross-section heteroskedasticity in the disturbances. **** significant at the 1% level; *** significant at the 5% level; ** significant at the 10% level; * significant at the 15% level.

Table 8 - Restriction tests (regressions [6]-[12])

Dependent variable : Seigniorage

	[6]	[7]	[8]	[9]	[10]	[11]	[12]
Instruments List	III	III	II	III	III	V	III
Sargan Test p-value	0.997	0.998	0.964	0.998	0.999	0.955	0.967
First stage: Shea-Godfrey statistic Partial R2	0.287	0.292	0.383	0.416	0.351	Seigniorage: 0.171 Seigniorage squared: 0.302	0.612
First stage: Stock-Yogo statistic Partial F	14.410	14.191	9.632	8.368	8.546	43.917(a)	13.160

Instruments. List II: seigniorage(-1), CBindep, CBturnover; List III: seigniorage(-1), CBturnover; List V: seigniorage(-1), CBturnover, seigniorage(-1)squared, CBturnover squared.
(a) computed on the predicted non linear combination of seigniorage from the PTSLS estimation

In line with previous findings (Arcand et al., 2008) a real appreciation of the local currency (an increase in *REER*) reduces deforestation. The intuition is that it slows down land clearing for the agricultural export sector expansion and penalizes the profitability of logging activities for export. One could suspect that the seigniorage is correlated with a real appreciation; however, the introduction of this variable does not modify the marginal impact of the seigniorage variable (equation [10] in *Table 7*).[10] Hence, the variable *Seigniorage* really catches a substitution effect in the government financing, independently of an eventual modification in non-tradable versus tradable goods prices.

At last, we show that our results still hold if we control by the aid (*Aidgni*) or by the instability of the real exchange rate (in particular, the aid has a negative and significant effect on deforestation) in equation [12] in *Table 7*). It is indeed assumed that aid flows may dampen the pressure on natural resources depletion and more specifically be designated to finance the incremental costs of global public goods in developing countries as suggested by Kaul and al. 2003. The instability of the real exchange rate (*Reerins*) helps capture a characteristic of developing countries that often exhibit macroeconomic instability: *Reerins* as a negative sign in equation [12] as expected but is weakly significant.

[10] Note that *Reer* is computed without taking into account oil exporters in the calculation of the weighting of the main trade partners. Introducing oil exporters does not change the results.

Group 2: Non linear effects of seigniorage on deforestation

Next, we explore the existence of a nonlinear effect of seigniorage on deforestation. To put it differently, it would be interesting to search for the existence of seigniorage level above/below which seigniorage and deforestation would be complements.

We allow in regression [11 for a quadratic form of seigniorage. This simple form to account for non linearities yields significant U-curves. Consequently, seigniorage and forest are still substitutes below the threshold (about 125% seigniorage ratio) and complements above this value. This finding deserves several remarks. First, the absence of a trade-off between seigniorage and forest at such high levels of seigniorage (above the threshold) may reflect a poor management of macroeconomic and/or environmental policies). Second, there exists a very limited set of pairs of periods-countries that are concerned with this phenomenon. Third, and most important, the trade-off between seigniorage and forest revenues appears very robust at low levels of seigniorage (in particular, it still holds when considering non linearities). Since monetary policy recommendations for developing countries are precisely targeting these low levels of seigniorage, they would probably lead, in the light of our theoretical model and econometric evidence, to a deterioration of the forest surface.

To summarize, irrespective of control variables and their measure or of the different instruments used for the first stage regressions, seigniorage has *always* a negative and significant effect on deforestation, as emphasized in our theoretical model. Consequently, it would be interesting to propose an estimation of the magnitude of this negative effect. On the basis of regression [4], a 10% increase in seigniorage reduces the average deforestation rates by 1.4% (and the reduction in deforestation may climb up to 3.9% if we consider regression [5]). This result confirms that there exist a non-negligible trade-off between macroeconomic goals and environmental objectives.

3. Protecting the forest in low-inflation developing countries: a solution

According to our model, supported by empirical evidence, there exists a non-negligible substitution effect between seigniorage revenues and deforestation revenues in developing countries. As a consequence, countries that launch into inflation stabilization programs may experience an increase in their deforestation rate. The purpose of this section is to try to develop a solution to this problem. We focus on an international mechanism which is justified by the fact that forest generates international spillovers. For instance forests are the second biggest stock of carbon on earth after oceans, therefore contributing to mitigate climate change. They provide a habitat for between 50 and 90 per cent of the total biodiversity of the planet. Deforestation and forest degradation are among the most important sources of emissions of greenhouse gases, just behind the energy sector, contributing about 20 per cent of the overall greenhouse gases entering the atmosphere (Intergovernmental Panel on Climate Change, IPCC), and forest clearance is responsible for the extinction of many species. Consequently, the preservation of equatorial and tropical forests is now a global issue on the agenda of international environmental negotiations, especially the United Nations Framework Convention on Climate Change (UNFCCC) and the Convention on Biological Diversity. Thus, deforestation is a direct clause of concern for "international agencies" who might attempt to implement a transfer scheme for "avoided deforestation" (such as the United Nations program on Reducing Emissions from Deforestation and Degradation-REDD),[11] all the more that deforestation and forest degradation are taking place at an extremely rapid pace.

The optimal contract can be viewed as a win-win strategy: effectively, under the optimal contract, a lower inflation target does not encourage governments to resort to resource depletion, and might even reduce the depletion of natural resources. Thus, the model may justify the intervention of an international agency, who implements a transfer scheme in order to limit deforestation, with optimal rewards/penalties being contingent to the current inflation target.

[11] In December 2005, the United Nations Framework Convention on Climate Change developed an agenda item on "Reducing emissions from deforestation in developing countries and approaches to stimulate action". The REDD Program is aimed at generating transfer flows of resources to reduce global emissions from deforestation and forest degradation. The REDD scheme currently under examination, as defined by the 2007 Bali meeting of the UNFCCC, proposes that developed countries pay developing countries for CO2 emissions saved through avoided deforestation. A multi-donor trust fund was established in July 2008 that allows donors to pool resources and provides funding to activities towards this Program.

One way to avoid that a tighter monetary policy (a lower $\bar{\pi}$) decreases optimal deforestation (f^*) is to consider the presence of a Supra-Authority (Principal) that aims at protecting the forest. To achieve this goal, the Principal transfers to Government $\omega > 0$ units of revenue per each unit of deforestation below a target $\tilde{f}$, namely $\omega(\tilde{f} - f)$.[12] Consequently, the Government maximizes the following welfare function:

$$L^g = -\frac{1}{2}\left\{(\pi - \bar{\pi})^2 + \lambda\left[\alpha(\pi - \pi^e) + \beta(\phi f + \pi)\right]^2 + \mu(f - \bar{f})^2\right\} + \omega(\tilde{f} - f) \qquad (10)$$

Since L^g is still convex in its arguments, we find the optimal inflation and deforestation values using the first order conditions (recall that, in the absence of stochastic shocks, $\pi = \pi^e$ ex-post):

$$/\pi: \quad (\pi - \bar{\pi}) + \lambda(\alpha + \beta)\beta(\phi f + \pi) = 0 \qquad (11a)$$

$$/f: \quad -\lambda\phi\beta^2(\phi f + \pi) - \mu(f - \bar{f}) - \omega = 0 \qquad (11b)$$

From (11a-b), we easily derive the equilibrium values, with $A \equiv 1 + \lambda\beta(\alpha + \beta) > 0$:

$$f^*(\omega) = \frac{\mu A\bar{f} - \lambda\phi\beta^2\bar{\pi} - \omega A}{\lambda\phi^2\beta^2 + \mu A} \qquad (12a)$$

$$\pi^*(\omega) = \frac{\bar{\pi}(\lambda\phi^2\beta^2 + \mu) - \lambda\beta\phi\mu(\alpha + \beta)\bar{f} + \lambda\beta\phi(\alpha + \beta)\omega}{\lambda\phi^2\beta^2 + \mu A} \qquad (12b)$$

Remark that $-\bar{\pi}$ and ω exert opposite effects on the optimal deforestation rate f^* in (12a). Following the adoption of a tighter monetary policy ($d\bar{\pi} < 0$), we can compute the change in ω that keeps forest constant ($df^* = 0$) by writing the total differential of $f^* \equiv f^*(\bar{\pi}; \omega)$:

$$\left.\frac{d\omega}{d\bar{\pi}}\right|_{df^*=0} = -\frac{\partial f^* / \partial \bar{\pi}}{\partial f^* / \partial \omega} \Leftrightarrow d\omega = \frac{\lambda\beta^2\phi}{1 + \lambda\beta(\alpha + \beta)}(-d\bar{\pi}) \qquad (13)$$

---

[12] Our results are unchanged if we define the transfer as $\omega(1 - f / \tilde{f})$, and in this case optimal deforestation (f^*) would positively depend on the Principal's deforestation target ($\tilde{f}$), i.e. a tighter deforestation target reduces optimal deforestation. Moreover, we suppose that $\tilde{f} < \bar{f}$, since Principal's interest for protecting the forest is more important with respect to Government (but results still hold for any $\tilde{f}$ value, including $\tilde{f} \geq \bar{f}$).

First, observe that the subsidy is rising when the monetary policy is more restrictive ($d\bar{\pi} < 0$). Allowing for a sufficiently high increase in ω prevents deforestation from raising; in this case, lower inflation and forest protection are no longer conflicting goals. Second, the magnitude of the subsidy depends positively on the quality of institutions ϕ. Since the quality of institutions is relatively low in developing countries, our result exhibits an interesting incentive to put in place such a subsidy system in order to protect forests, because of a potentially relatively reduced cost. Finally, the size of the subsidy ($d\omega$) must be more important as the stabilization program $(d\bar{\pi})$ is more aggressive.

With respect to these findings, let us highlight two points. On the one hand, remark that we have implicitly assumed that Principal chooses to increase ω to prevent deforestation ($df^* \leq 0$), by setting the appropriate magnitude (namely $d\omega / d\bar{\pi}$ that prevents an increase in forest depletion). On the other hand, the mere purpose of this transfer is to prevent deforestation. However, one may argue that ω should be chosen optimally, as the transfer that maximizes Principal's welfare, which is defined as:[13]

$$W = -\frac{1}{2}\left\{(\pi^*(\omega))^2 + \lambda\left[\beta(\phi f^*(\omega) + \pi^*(\omega))\right]^2 + \mu\left(f^*(\omega) - \tilde{f}\right)^2\right\} \tag{14}$$

Compared to Government, the Principal targets a zero inflation rate (results are unchanged for a non-zero target $\tilde{\pi} < \bar{\pi}$), has perfect expectations ($\pi = \pi^e$ ex-ante) and pursue a different forest target $\tilde{f} < \bar{f}$ (results are unchanged for any value of $\tilde{f}$). To maximize welfare W, the Principal internalizes Government's optimal inflation and deforestation values $\pi^*(\omega)$ and $f^*(\omega)$ from (12a-b), and chooses the optimal transfer ω^*, defined as $\left.\frac{dW}{d\omega}\right|_{\omega=\omega^*} = 0$:

$$\omega^* = \frac{\mu AB\left(\bar{f} - \tilde{f}\right) + \alpha\lambda^2\beta^2\phi^2\mu(\alpha+\beta)\bar{f} - \lambda\beta\phi\left[\beta B + \alpha\left(\mu + \lambda\beta^2\phi^2\right)\right]\bar{\pi}}{\alpha\lambda^2\beta^2\phi^2(\alpha+\beta) + AB} \tag{15}$$

$$\textit{with}\;\; B \equiv \mu A + \lambda\beta^2\phi^2 > 0 \;\; \textit{and} \;\; A \equiv 1 + \lambda\beta(\alpha+\beta) > 0$$

[13] An alternative solution is to compute the optimal deforestation target for the Principal, namely $\tilde{f}^*$, with no subsidy ($\omega = 0$) and the term $\mu\left(f - \bar{f} - \tilde{f}\right)$ in the Government's welfare function (10). Using ω or $\tilde{f}$ as an instrument might be easier to implement compared to a program in which the Principal chooses the quality of institutions ϕ, since changing institutions is more difficult than proposing a supra-national subvention/penalty program (as, for example, the pollution quotas established by the Kyoto Protocol).

Observe in (15) that, in order to maximize welfare, the Principal must increase the optimal transfer ω^* following the adoption of a tighter monetary policy (a lower $\bar{\pi}$).

We may now compute the effect of $\bar{\pi}$ on the optimal deforestation as:

$$\frac{df^*(\bar{\pi};\omega^*(\bar{\pi}))}{d\bar{\pi}} = \frac{1}{B}\left[-\lambda\beta^2\phi - A\frac{d\omega^*(\bar{\pi})}{d\bar{\pi}}\right] = \frac{\alpha\lambda\beta\phi}{\alpha\lambda^2\beta^2\phi^2(\alpha+\beta)+AB} > 0 \qquad (16)$$

Contrary to the case $\omega = 0$, where a tighter monetary target was increasing optimal deforestation (see relation (6a)), a lower inflation target $d\bar{\pi} < 0$ is *decreasing* optimal deforestation in (16), namely $df^* < 0$. Consequently, subsidizing forest protection upturns the positive correlation between a tighter monetary policy and deforestation. Moreover, the transfer that allows for inflation and deforestation objectives not to be contradictory can be defined as part of an optimal scheme, in which the Principal sets the transfer in order to maximize welfare.

4. Conclusion

This paper is one of the first attempts to bridge a gap between two aspects of economic policies in developing countries that are usually considered in isolation: natural resources depletion and monetary policies. Indeed, including environmental objectives in Governments' preoccupations and considering the potential impact of macroeconomic objectives on the environment may provide a way to impede the deforestation process that affected developing countries in the last decades.

In developing countries with an important forest area, forest revenues and seigniorage are two important resources for Government revenues. Building on this idea, we propose a simple theoretical model showing that Governments may trade off revenues generated by forest depletion with revenues generated by seigniorage. The evidence proposed by our econometric analysis, performed on a sample of developing countries with important forest, corroborates the existence of an arbitrage between forest conversion and seigniorage revenues.

Consequently, our paper asserts that, in the absence of some compensating revenues, there exists a trade-off between macroeconomic performances (inflation) and the environment (deforestation policies). One should of course be cautious in concluding that macroeconomic policies are the main drivers of deforestation; our results only suggest that, in some developing countries, the conversion of forests that are often state-owned may generate important revenues to public budgets. Hence, the efficiency of usual environmental policies aimed at promoting sustainable forest management may be reduced in the presence of macroeconomic objectives such as downsizing seigniorage revenues.

Furthermore, our findings shed a different light on macroeconomic policies that restrict seigniorage revenues by fighting inflation (such as, for example, IMF's recommendations for tighten monetary policies, including inflation targeting or exchange rate control). Failing to provide for some compensating revenues may lead Governments to accept a higher deforestation rate in countries where revenues from forests are important and, more generally, in countries where revenues from natural resources depletion are significant. This is particularly supported by a recent survey by López (2006, in López & Toman, p. 157), who recalls that countries under structural adjustments programs under-invest in their human and environmental assets.

Consequently, our conclusions support the recent debate on the necessity of some form of rewarding for countries combating climate change by reducing deforestation and forest degradation with the United Nations Program on Reducing Emissions from Deforestation and Forest Degradation in Developing Countries (REDD) (e.g. Combes-Motel, Combes & Pirard, 2009). Subsidizing countries that limit deforestation or developing countries that launch into macroeconomic stabilization policies (by fighting inflation, for example), may be a virtuous way to prevent forest depletion.

References

- Aisen, A. and Veiga, F., 2008 "The political economy of seigniorage" *Journal of Development Economics* 87, pp. 29-50.
- Alesina, A. and Tabellini, G., 1987 "Rules and discretion with noncoordinated monetary and fiscal policies" *Economic Inquiry* 25, pp. 619-630.
- Angelsen, A. and Kaimowitz, D., 2000 "Rethinking the Causes of Deforestation: Lessons from Economic Models" *World Bank Research Observer* 14, pp. 73-98.
- Arcand, J.-L., Guillaumont, P., and Guillaumont-Jeanneney, S., 2008 "Deforestation and the Real Exchange Rate" *Journal of Development Economics* 86, pp. 242-262.
- Barbier, E., 2004 "Explaining Agricultural Land Expansion and Deforestation in Developing Countries" *American Journal of Agricultural Economics* 86, pp. 1347-1353.
- Barro, R. and Gordon, D., 1983 "Rules, discretion, and reputation in a model of monetary policy" *Journal of Monetary Economics* 12, pp. 101-122.
- Bhattarai, M. and Hammig, M., 2004 "Governance, economic policy, and the Environmental Kuznets curve for natural tropical forests", *Environment and Development Economics* 9, pp. 367-382.
- Combes-Motel, P., Combes, J.-L. and Pirard, R., 2009 "A methodology to estimate impacts of domestic policies on deforestation: Compensated Successful Efforts for 'avoided deforestation' (REDD)" *Ecological Economics* 68, pp. 680-691.
- Cropper, M. and Griffiths, C., 1994 "The Interaction of Population Growth and Environmental Quality" *American Economic Review* 84, Papers and Proceedings of the Hundred and Sixth Annual Meeting of the American Economic Association, pp. 250-254.
- Crowe, C. and Meade, E., 2007 "Evolution of Central Bank Governance around the World" *Journal of Economic Perspectives* 21, pp. 69-90.
- Culas, R., 2007 "Deforestation and the Environmental Kuznets Curve: An Institutional Perspective" *Ecological Economics* 61, pp. 429-437.
- Cukierman, A., Edwards, S. and Tabellini, G., 1992 "Seigniorage and political instability" *American Economic Review* 82, pp. 537-555.
- FAO, 1997 State of the World's Forests, available on line at the address: http://www.fao.org/docrep/W4345E/w4345e00.htm.
- Faria, J.R., 1998 "Environment, Growth and Fiscal and Monetary Policy" *Economic Modelling* 15, pp. 113-123.
- Foster, A. and Rosenzweig, M., 2003 "Economic Growth and the Rise of Forests" *Quarterly Journal of Economics* 118, pp. 601-638.
- Godfrey, L., 1999 "Instrument Relevance in Multivariate Linear Models" *Review of Economics and Statistics* 81, pp. 550-552.
- IMF, 2006 "De Facto Classification of Exchange Rate Regimes and Monetary Policy Framework", available on line at the address: http://www.imf.org/external/np/mfd/er/2006/eng/0706.htm.
- Kahn, J.R. and McDonald, J.A., 1994 "Third-World Debt and Tropical Deforestation", *Ecological Economics* 12, pp. 107-123
- Karsenty, A., 2007 "Overview of Industrial Forest Concessions and Concession-based Industry in Central and West Africa and Consideration of Alternatives", available on line at the address: http://www.cirad.fr/ur/ressources_forestieres/publications_et_colloques_ateliers.
- Kaul, I., Conceição, P., Le Goulven, K. and R.U. Mendoza, 2003 *Providing Global Public Goods. Managing Globalization*, Oxford University Press.
- Koop, G. and Tole, L., 2001 "Deforestation, Distribution and Development" *Global Environmental Change* 11, pp. 193-202.
- López, R. and Toman, M., 2006 *Economic Development and Environmental Sustainability*, Oxford University Press.
- Minea, A. and Villieu, P., 2009 "Threshold Effects in Monetary and Fiscal Policies in a Growth Model: Assessing the Importance of the Financial System" *Journal of Macroeconomics* 31, pp. 304-319.
- Munasinghe M., 1999 "Special Topic 1: Structural Adjustment Policies and the Environment" *Environment and Development Economics* 4, pp. 9-18.

- Polillo, S. and Guillén, M., 2005 "Globalization Pressures and the State: The Global Spread of Central Bank Independence" *American Journal of Sociology* 110, pp. 1764-1802.
- Sargan, J., 1988 "Testing for Misspecification After Estimating Using Instrumental Variables" in Maasoumi, E. (ed.) Contribution to Econometrics: John Denis Sargan, 1, Cambridge University Press.
- Saunders, J, Ebeling, J. and Nussbaum, R., 2008 "Reduced Emissions from Deforestation and Forest Degradation (REDD): Lessons from a forest governance perspective", available on-line at the address: http://www.illegal-logging.info/item_single.php?item=document&item_id=620&approach_id=1
- Stock, J., Wright, J. and Yogo, M., 2002 "A Survey of Weak Instruments and Weak Identification in Generalized Methods of Moments" *Journal of Business and Economic Statistics* 20, pp. 518-529.
- Strand J. and Mundaca, B.G., 2006 "Impacts of Macroeconomic Policies on the Environment, Natural Resources and Welfare in Developing Countries", in Lopez R. and Toman M. A. (eds.), *Economic Development and Environmental Sustainability*, Oxford University Press.
-

Appendix 1: Variables' description and definition

Variables	*Description*	*Source*
Dependent variable:		
Defor	Average annual deforestation rate, %	FAOstat
Explanatory variables:		
Interest variables		
Seigniorage	Seigniorage1: Change in reserve money ΔM over GDP.	ΔM in current LCU, IFS line 14a GDP in current LCU, World Development Indicators 2008
Control variables		
Log(Forest0	Initial forest area	FAO stat
Log(GDPPC and log(GDPPC squared	GDP per capita, constant 2000 USD	World Development Indicators 2008
Fraser	Area 5, regulation of credit, labor, business. An increase means an improvement.	The Fraser Institute
Civil	Civil liberty index. An increase means an improvement.	The Freedom house
Poptot	Population, total	World Development Indicators 2008
Urbpop	Urban population, percentage of total	World Development Indicators 2008
Growth	GDP per capita growth, annual %	World Development Indicators 2008
Gratioy	Government consumption, in % of GDP	Government consumption in current LCU, IFS line91; GDP in current LCU, World Development Indicators 2008
DebtBurden	Total debt service, in percentage of export of goods, services and income	World Development Indicators 2008

Xfuel	Fuel exports in percentage of merchandise exports	World Development Indicators 2008
Mineral	Mineral depletion in percentage of Gross National Income. Mineral depletion is equal to the product of unit resource rents and the physical quantities of minerals extracted (bauxite, copper, iron, lead, nickel, phosphate, tin, zinc, gold, and silver	World Development Indicators 2008
Reer	Real effective exchange rate, base 100 in 1990. Weights determined by the country's first ten partners (imports and exports), oil countries excluded or not. An increase means a real appreciation.	Authors' calculations
Aidgni	Aid flows in percentages of gross national income	World Development Indicators 2008
Reerins	Instability of Reer	Authors' calculations
Instruments		
CBturnover	Turnover of the Central Bank governors. An increase means a deterioration of CB governance	Crowe and Meade (2007). The original variable is available on 1980-1989 and 1995-2004. It is assumed that the 1980-1989 ratings pertain in period1 and period2; the 1995-2004 ratings pertain in period3 and period4. Moreover since no ratings were reported in African monetary unions, it is assumed that there was no temporal variability for these countries
CBindep	Cukierman index of Central Bank independence. An increase means an improvement of CB independance	Polillo and Guillén (2005). The original variable is available in 1989, 1995 and 2000. The 1989 ratings pertain in period1 and 2; the 1995 rating in period3; the 2000 rating in period4.

TECHNICAL APPENDICES (FOR REFEREES ONLY; NOT TO BE PUBLISHED)

Appendix A: Extent of and change in forested areas by geographic areas, 1990-2005

Regions	Areas					Annual Change rate			
	1990	2000	2005			1990-2000		2000-2005	
	1000 ha	1000 ha	1000 ha	% of land area	% of world forests	1000 ha/yr	%	1000 ha/yr	%
Total Eastern and Southern Africa	252 354	235 047	226 534	28		-1 731	-0,71%	-1 702	-0,74%
Total Northern Africa	146 093	135 958	131 048	9		-1 013	-0,72%	-982	-0,74%
Total Western and Central Africa	300 914	284 608	277 829	44		-1 631	-0,56%	-1 356	-0,48%
Total Africa	699 361	655 613	635 412	21,0%	16,1%	-4 375	-0,65%	-4 040	-0,63%
Total East Asia	208 155	225 663	244 862	21		1 751	0,81%	3 840	1,63%
Total South and South-east Asia	323 156	297 380	283 127	33		-2 578	-0,83%	-2 851	-0,98%
Total Western and Central Asia	43 176	43 519	43 588	4		34	0,08%	14	0,03%
Total Asia	574 487	566 562	571 577	18,0%	14,5%	-792	-0,14%	1 003	0,18%
Total Europe	989 320	998 091	1 001 394	43,6%	25,3%	877	0,09%	661	0,07%
Total North America	677 801	677 971	677 464	30,8%	17,1%	17	0,00%	-101	-0,01%
Total Caribbean	5 350	5 706	5 974			36	0,64%	54	0,92%
Total Central America	27 639	23 837	22 411			-380	-1,48%	-285	-1,23%
Total South America	890 818	852 796	831 540			-3 802	-0,44%	-4 251	-0,50%
Total Carribean, Central and South America	923 807	882 339	859 925	46,2%	21,8%	-4 146	-0,45%	-4 482	-0,51%
Total Oceania	212 514	208 034	206 254	24,1%	5,2%	-448	-0,21%	-356	-0,17%
Total World	4 077 291	3 988 610	3 952 025	29,5%	100%	-8 868	-0,22%	-7 317	-0,18%

Source: FAO, Global Forest Resources Assessment 2005, available on line: http://www.fao.org/forestry/32033/en/

Appendix B: List of Countries

Country Code	***Country name***	***Country Code***	***Country name***	***Country Code***	***Country name***
AGO	Angola	GIN	Guinea	NER	Niger
ARG	Argentina	GMB	Gambia, The	NGA	Nigeria
BDI	Burundi	GNB	Guinea-Bissau	NIC	Nicaragua
BEN	Benin	GNQ	Equatorial Guinea	NPL	Nepal
BFA	Burkina Faso	GTM	Guatemala	PAK	Pakistan
BGD	Bangladesh	GUY	Guyana	PAN	Panama
BLZ	Belize	HND	Honduras	PER	Peru
BOL	Bolivia	IDN	Indonesia	PHL	Philippines
BRA	Brazil	IND	India	PNG	Papua New Guinea
BTN	Bhutan	KEN	Kenya	PRY	Paraguay
BWA	Botswana	KHM	Cambodia	SDN	Sudan
CAF	Central African Republic	KOR	Korea, Rep.	SEN	Senegal
CHL	Chile	LAO	Lao PDR	SLE	Sierra Leone
CHN	China	LBR	Liberia	SLV	El Salvador
CIV	Cote d'Ivoire	LKA	Sri Lanka	SUR	Suriname
CMR	Cameroon	MDG	Madagascar	TCD	Chad
COG	Congo, Rep.	MEX	Mexico	TGO	Togo
COL	Colombia	MLI	Mali	THA	Thailand
CRI	Costa Rica	MNG	Mongolia	TZA	Tanzania
ECU	Ecuador	MOZ	Mozambique	UGA	Uganda
ERI	Eritrea	MRT	Mauritania	URY	Uruguay
ETH	Ethiopia	MWI	Malawi	VEN	Venezuela, RB
GAB	Gabon	MYS	Malaysia	VNM	Vietnam
GHA	Ghana	NAM	Namibia	ZAR	Congo, Dem. Rep.
				ZMB	Zambia
				ZWE	Zimbabwe

Note: The selected countries meet two conditions: being a developing and /or emerging country and having a forest area representing at least 10% of their total surface in period 1.

Appendix C: GDP per capita, average deforestation rates and seigniorage across countries and four periods

		70-79	80-89	90-97	98-05
AGO	**GDPPC**	Na	810	629	725
	Seigniorage	Na	Na	153,3%	6,7%
	Defor	0,0%	0,0%	0,1%	0,1%
ARG	**GDPPC**	6979	6613	7000	7499
	Seigniorage	6,7%	26,3%	9,0%	1,1%
	Defor	0,0%	0,0%	0,2%	0,2%
BDI	**GDPPC**	130	145	135	106
	Seigniorage	1,1%	0,5%	0,8%	1,0%
	Defor	0,0%	0,0%	1,5%	2,2%
BEN	**GDPPC**	285	296	280	315
	Seigniorage	0,7%	0,7%	0,8%	1,0%
	Defor	0,6%	0,6%	0,9%	1,1%
BFA	**GDPPC**	152	174	186	231
	Seigniorage	0,6%	0,6%	1,4%	-0,2%
	Defor	0,0%	0,0%	0,1%	0,2%
BGD	**GDPPC**	227	242	281	355
	Seigniorage	0,5%	0,4%	0,5%	0,6%
	Defor	0,1%	0,7%	0,0%	0,1%
BLZ	**GDPPC**	1487	1939	2840	3398
	Seigniorage	0,8%	0,5%	0,3%	0,4%
	Defor	-3,4%	0,0%	0,0%	0,0%
BOL	**GDPPC**	1054	917	924	1021
	Seigniorage	1,8%	115,9%	0,8%	0,7%
	Defor	0,0%	0,0%	0,2%	0,2%
BRA	**GDPPC**	2774	3404	3482	3744
	Seigniorage	1,3%	8,5%	27,8%	0,4%
	Defor	0,2%	-0,1%	0,2%	0,3%
BTN	**GDPPC**	Na	346	594	870
	Seigniorage	Na	1,1%	0,8%	1,0%
	Defor	0,0%	-0,7%	-0,1%	-0,1%
BWA	**GDPPC**	792	1685	2642	3799
	Seigniorage	0,6%	0,5%	0,2%	0,2%
	Defor	0,0%	0,0%	0,4%	0,4%
CAF	**GDPPC**	348	298	245	235
	Seigniorage	1,4%	1,2%	1,7%	-0,1%
	Defor	0,0%	0,0%	0,1%	0,1%
CHL	**GDPPC**	2175	2533	3918	5130
	Seigniorage	10,7%	0,8%	0,6%	0,2%
	Defor	0,0%	0,0%	-0,2%	-0,2%
CHN	**GDPPC**	143	277	572	1096
	Seigniorage	Na	3,0%	3,0%	1,6%
	Defor	0,3%	0,3%	-0,5%	-0,8%
CIV	**GDPPC**	980	782	613	597
	Seigniorage	1,9%	0,3%	1,0%	0,3%
	Defor	0,0%	0,1%	0,0%	-0,1%

	70-79	80-89	90-97	98-05
CMR	574	854	616	651
	0,9%	0,5%	0,0%	0,2%
	0,0%	0,0%	0,4%	0,4%
COG	811	1230	1078	1027
	1,1%	0,7%	0,6%	0,8%
	0,0%	0,0%	0,0%	0,0%
COL	1391	1669	1999	2064
	1,5%	1,0%	1,0%	0,8%
	0,3%	0,0%	0,0%	0,0%
CRI	2827	2916	3425	4140
	1,1%	1,4%	0,9%	0,3%
	1,5%	0,8%	0,3%	0,1%
ECU	1154	1304	1331	1402
	1,1%	-0,2%	0,3%	-0,4%
	0,2%	0,0%	0,7%	0,7%
ERI	na	na	180	183
	na	na	6,5%	5,2%
	na	na	na	0,1%
ETH	na	121	110	123
	na	0,8%	1,3%	0,8%
	na	na	1,1%	0,5%
GAB	5336	4943	4717	4373
	1,3%	0,3%	0,4%	0,2%
	0,0%	0,0%	0,0%	0,0%
GHA	259	201	222	257
	0,0%	0,0%	0,0%	0,0%
	0,0%	0,0%	0,8%	0,9%
GIN	337	331	346	388
	na	na	0,4%	1,3%
	0,0%	0,0%	0,3%	0,3%
GMB	291	316	303	303
	1,6%	1,3%	0,9%	1,9%
	0,0%	0,0%	-0,2%	-0,2%
GNB	178	167	187	143
	na	6,6%	4,3%	1,9%
	0,0%	0,0%	0,2%	0,2%
GNQ	na	614	813	4920
	na	-0,4%	0,1%	0,7%
	0,0%	0,0%	0,4%	0,4%
GTM	1458	1485	1538	1706
	0,8%	0,7%	0,9%	0,6%
	0,5%	-0,5%	0,5%	0,6%
GUY	813	695	776	988
	1,4%	5,3%	3,7%	0,9%
	0,5%	0,0%	0,0%	0,0%

Appendix C (continued)

		70-79	80-89	90-97	98-05
HND	**GDPPC**	825	887	917	980
	Seigniorage	0,9%	0,6%	1,4%	0,7%
	Defor	0,0%	0,0%	1,3%	1,4%
IDN	**GDPPC**	298	473	759	841
	Seigniorage	na	0,8%	0,7%	1,0%
	Defor	0,2%	0,3%	0,7%	0,9%
IND	**GDPPC**	217	263	352	489
	Seigniorage	1,0%	1,3%	1,5%	1,4%
	Defor	-0,1%	0,0%	-0,2%	-0,1%
KEN	**GDPPC**	382	426	424	412
	Seigniorage	0,9%	0,7%	1,1%	0,4%
	Defor	0,0%	0,0%	0,1%	0,1%
KHM	**GDPPC**	na	na	224	316
	Seigniorage	na	na	0,5%	0,7%
	Defor	0,0%	0,4%	0,5%	0,8%
KOR	**GDPPC**	2530	4459	8332	11464
	Seigniorage	1,6%	0,6%	0,5%	0,1%
	Defor	0,0%	0,1%	0,0%	0,0%
LAO	**GDPPC**	na	215	260	356
	Seigniorage	na	na	0,5%	0,6%
	Defor	0,3%	0,4%	0,2%	0,2%
LBR	**GDPPC**	817	601	108	152
	Seigniorage	na	1,0%	na	0,3%
	Defor	0,0%	0,0%	0,7%	0,8%
LKA	**GDPPC**	374	506	663	883
	Seigniorage	1,2%	1,1%	0,8%	0,6%
	Defor	0,2%	-0,7%	0,5%	0,6%
MDG	**GDPPC**	369	284	240	231
	Seigniorage	0,7%	0,9%	1,3%	1,0%
	Defor	0,0%	0,0%	0,2%	0,2%
MEX	**GDPPC**	4080	4985	5123	5863
	Seigniorage	1,2%	2,6%	0,8%	0,6%
	Defor	0,5%	0,0%	0,2%	0,2%
MLI	**GDPPC**	232	221	215	260
	Seigniorage	1,8%	0,4%	1,0%	1,3%
	Defor	0,0%	0,0%	0,3%	0,3%
MNG	**GDPPC**	na	482	434	493
	Seigniorage	na	na	4,5%	1,2%
	Defor	-0,1%	0,4%	0,3%	0,3%
MOZ	**GDPPC**	na	179	190	263
	Seigniorage	na	0,0%	0,0%	0,0%
	Defor	0,0%	0,0%	0,1%	0,1%
MRT	**GDPPC**	477	439	419	424
	Seigniorage	1,1%	0,8%	0,1%	0,0%
	Defor	0,1%	0,1%	1,1%	1,4%

	70-79	80-89	90-97	98-05
MWI	147	146	138	142
	0,5%	0,6%	1,5%	1,1%
	0,0%	0,0%	0,4%	0,4%
MYS	1405	2082	3175	3921
	1,5%	0,8%	0,8%	0,3%
	0,0%	-0,2%	0,2%	0,2%
NAM	na	1817	1697	1911
	na	na	0,5%	0,2%
	0,0%	0,0%	0,4%	0,4%
NER	270	221	175	167
	0,9%	0,3%	0,1%	0,5%
	0,0%	0,0%	1,6%	0,8%
NGA	427	349	370	383
	1,0%	1,2%	2,2%	1,1%
	0,0%	0,1%	1,1%	1,4%
NIC	1347	899	664	780
	1,2%	321,7%	145,7%	0,6%
	1,0%	1,2%	0,7%	0,6%
NPL	141	156	194	228
	0,9%	1,4%	2,2%	0,9%
	0,6%	0,2%	0,9%	0,7%
PAK	288	393	500	548
	1,9%	2,0%	1,7%	1,5%
	0,1%	-0,9%	0,7%	0,9%
PAN	3005	3225	3373	4014
	na	na	na	0,0%
	0,3%	1,1%	0,1%	0,0%
PER	2197	2128	1816	2153
	1,7%	23,0%	41,9%	0,4%
	0,0%	0,0%	0,1%	0,1%
PHL	845	919	910	1020
	0,8%	0,9%	0,8%	0,5%
	1,1%	-0,4%	1,2%	1,0%
PNG	613	565	650	620
	0,2%	0,2%	0,3%	0,3%
	0,0%	0,0%	0,2%	0,2%
PRY	1011	1387	1438	1352
	1,2%	1,2%	1,2%	0,6%
	0,1%	1,6%	0,4%	0,4%
SDN	285	280	302	395
	0,0%	0,0%	0,1%	0,0%
	0,0%	0,0%	0,3%	0,4%
SEN	495	459	426	464
	0,8%	0,7%	0,3%	0,8%
	0,0%	0,0%	0,2%	0,2%

Appendix C (continued)

		70-79	80-89	90-97	98-05
SLE	**GDPPC**	279	278	208	177
	Seigniorage	1,0%	4,5%	2,8%	1,3%
	Defor	0,0%	0,0%	0,3%	0,3%
SLV	**GDPPC**	2110	1624	1861	2137
	Seigniorage	1,2%	0,1%	-0,1%	-0,3%
	Defor	1,0%	1,4%	0,6%	0,7%
SUR	**GDPPC**	2660	2239	2036	2245
	Seigniorage	1,3%	3,8%	13,4%	3,5%
	Defor	0,0%	0,0%	0,0%	0,0%
TCD	**GDPPC**	202	170	177	202
	Seigniorage	1,0%	0,7%	0,7%	0,6%
	Defor	0,0%	0,0%	0,3%	0,3%
TGO	**GDPPC**	307	290	246	245
	Seigniorage	1,5%	0,4%	1,3%	0,1%
	Defor	0,0%	0,0%	1,4%	1,9%
THA	**GDPPC**	620	986	1854	2153
	Seigniorage	1,1%	0,7%	0,9%	0,7%
	Defor	1,4%	0,5%	0,3%	0,2%
TZA	**GDPPC**	na	257	255	286
	Seigniorage	na	1,9%	1,9%	0,8%
	Defor	0,0%	0,0%	0,4%	0,5%
UGA	**GDPPC**	na	167	191	247
	Seigniorage	2,0%	4,5%	na	0,6%
	Defor	0,2%	0,0%	0,8%	1,0%
URY	**GDPPC**	4343	4741	5643	6104
	Seigniorage	4,3%	2,7%	2,1%	0,3%
	Defor	0,0%	0,0%	-2,0%	-0,9%
VEN	**GDPPC**	6258	5134	5125	4691
	Seigniorage	0,0%	0,0%	0,0%	0,0%
	Defor	0,4%	-1,4%	0,2%	0,3%
VNM	**GDPPC**	na	207	281	441
	Seigniorage	na	na	3,3%	2,7%
	Defor	0,4%	1,1%	-1,0%	-0,9%
ZAR	**GDPPC**	307	239	139	87
	Seigniorage	0,8%	2,9%	215,3%	36,7%
	Defor	0,1%	0,3%	0,2%	0,1%
ZMB	**GDPPC**	531	417	338	325
	Seigniorage	0,6%	1,8%	4,2%	0,7%
	Defor	0,1%	-0,1%	0,4%	0,4%
ZWE	**GDPPC**	629	613	626	545
	Seigniorage	Na	0,0%	0,0%	0,0%
	Defor	0,0%	0,3%	0,6%	0,7%

Source: Authors' calculations from FAO, IFS, and WBI databases.