

Deforestation and credit instability in Latin American countries

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Abstract

This paper highlights the link between deforestation and credit instability in Latin American countries which exhibit strong deforestation rates as well as macroeconomic instability that is often rooted in the alternating episodes of credit booms and crunches. Pieces of explanation establishing a causal link between credit instability and deforestation driven by agricultural expansion are put forward. A key ingredient of the model is the existence of two sectors: a labour intensive agricultural sector and a capital-intensive one, the former relying only on land and labour and the latter using three production factors: capital, labour and land. Land is a specific factor within each sector. Land increases are deemed to be mainly an irreversible deforestation process; land decreases barely coincide with forest cover increases. Deforestation occurs in response to changes in the opportunity cost of capital, primarily because of the irreversible character of forest conversion. Econometric tests are performed on the 1948-2005 period and on a sample of Latin American countries. Controlling for the effects of macroeconomic policies and usual deforestation determinants, a positive and significant impact of credit instability on deforestation is found. Robustness checks including different specifications do not contradict this result. Sound macroeconomic policies have also significant positive environmental effects.

Keywords : Deforestation, credit instability, Latin America

JEL : O13, Q23, O23, O54

1. Introduction

Latin American countries have experienced a rapid deforestation: annual average deforestation rates in the most recent periods are twice the world's ones: 0.46% versus 0.22% over the 1990-2000 period and 0.51% versus 0.18% over the 2000-2005 period. Since primary forests in these countries account for 56% of the world's forests, the Latin American paces of deforestation raise particular concern and have emerged as an international issue related to global warming and biodiversity losses.¹ Forest preservation sustains the objectives of the United Nations Framework Convention on Climate Change. The Cancun climate agreement still recognises the role of forests as carbon absorbers. Moreover, forest preservation in Latin American countries meets also the objectives of the Convention on Biological Diversity in as much as at least 10 Latin American countries have more than 1,000 native tree species (FAO 2005) and a great amount of species extinction occurs in tropical environments (Myers 1993).

National initiatives remain however important but rely on the understanding of the deforestation process which has been extensively studied. According to Geist and Lambin (Geist & Lambin 2002), "source" or "proximate" causes of deforestation relate mainly to economic activities taking place at the local level such as investments in infrastructure and road networks (Angelsen 1999; Chomitz & Gray 1996), expansion of cattle ranching and agricultural activities (Barbier 2004b) and finally commercial logging (Van Kooten & Folmer 2004). Geo-ecological factors such as soil quality, rainfall and temperature conditions are considered as "predisposing" factors of deforestation which condition the links between "proximate" and "underlying" causes. The latter operate mainly at the macro level and are related to social processes and economic policies such as the population pressure (Carr 2003; Cropper & Griffiths 1994), landownership and income distributions, national and regional development strategies (Koop & Tole 2001), agricultural research and technological change as well (Southgate et al. 1990). The poor quality of institutions tends to accompany deforestation. Weakness of property rights creates incentives to capture rents generated by forest extraction (Deacon 1999). Inappropriate rules of law may incite forest dwellers to become agents of deforestation (Southgate & Runge 1990). Moreover, bribes and

¹ Climate change from forest conversion may also occur locally (Tinker et al. 1996) and preserving biodiversity also yields domestic benefits (Chomitz & Kumari 1998).

agricultural lobbies generate rural subsidies that both encourage low agricultural productivity and deforestation (Bulte et al. 2007).

Other studies have highlighted the role played by macroeconomic - fiscal, exchange rate and / or sectoral - policies in the deforestation process (Anderson 1990; Cattaneo & San 2005). Exchange rate depreciation promotes exporting sectors and by the way forest conversion. Exchange rate variations may however have an ambiguous impact on deforestation, depending on their permanent or transitory patterns (Arcand et al. 2008). Moreover, if a country relies on its export earnings, an increase in the terms of trade will reduce the long term forest stock (Barbier & Rauscher 1994). Openness may however dampen the effect of population pressure on forests when giving new opportunities for the economy (Hecht et al. 2006). The size of external debt may either give an incentive to increase exports revenues (and then foster forest harvesting) or to cut the extension of transport infrastructure (that dampens—deforestation). So, the overall effect of external debt is not theoretically clearcut (e.g. Angelsen & Kaimowitz 1999; Culas 2006), and weakly significant in the Latin America context (Gullison & Losos 1993).

This paper provides further investigations into underlying causes related to a peculiar macroeconomic feature of Latin American countries, i.e. the existence of large credit cycles defined as successive expansion and slowdown phases in the supply of credit and thus in sharp variations in the opportunity cost of capital. Credit allows financing investments in infrastructures that boost deforestation (Ferraz 2001; Pacheco 2006). It may also ease the adoption of more capital intensive agriculture which is less forest consuming (Angelsen 1999; Caviglia-Harris 2003). The main contribution of this paper is rather to focus on the detrimental impact of credit instability (and not only the credit growth path) on deforestation. Four methodological points need to be emphasized. First, we intend to analyse the effects of the variations of the opportunity cost of capital for borrowers, whatever the source of this variation (monetary policy, external shock, political instability, etc...). Second, we argue that these variations may be captured by evolutions in credit amounts, since variations of credit are mainly driven by credit supply movements. Third, the behaviour of agents involved in the deforestation process in Latin America is assumed to be mainly driven by short-term considerations. Fourth, the effects of deforestation are irreversible.

The remainder of the paper is organized as follows. Section 2 puts forwards stylised facts relating deforestation and credit cycles in Latin America. Section 3 justifies our main assumptions and offers a theoretical framework of the engines of deforestation linked to the opportunity cost of capital. Section 4 provides some econometric results and Section 5 concludes.

2. *Deforestation and credit instability in Latin American countries*

2.1. Why focusing on credit instability?

Latin American countries have experienced strong credit instability and pronounced credit cycles characterised by phases of strong acceleration of credit growth (credit or lending booms) followed by a drastic reduction in credits (credit crunches) from world war II onwards (e.g. Caballero 2000). The first three decades (50s to 70s) are marked by a rapid credit expansion, with several deceleration episodes (see Figure 1 in the statistical appendix). Tight credit policies in the 80s are combined with financial repression in the aftermath of the debt crisis. The financial liberalisation in the late 80s spurred a credit expansion in the early 90s followed by a credit stagnation episode since the late 90s (Barajas & Steiner 2002b).² More generally, credit cycles either occur with economic policies reversals (e.g. the Brazilian experience of tight credit against inflation in the 60s (Randall 1997);³ or the adoption of the Basel Accord in the 90s (Barajas et al. 2004); or fluctuations in international liquidity availability as well (e.g. petrodollars in the 70s (Amado et al. 2006)). Braun & Hausmann (2002) have shown that the frequency of credit crunches is higher in Latin America than in other developing countries; these credit crunches are deeper in magnitude and relatively long-lived. They also argue that the recent episodes of credit crunches have been more frequent and severe than before. Credit cycles are thus a prominent feature of Latin American countries for many years and are a key ingredient of their macroeconomic instabilities (Edwards 1995).⁴

² Financial reforms were implemented at different times in Latin American countries. Chile and Mexico were among the first reformers in the mid-80's while Dominican Republic and Ecuador liberalised only in the mid-90's.

³ The military government implemented a sharp tightening of credit when it seized the power in 1964 in Brazil

⁴ Three pieces of explanation can be put forward to understand this fact: (i) a poor financial development (weak banking supervision, limited access to collateral) leads to strong moral hazard problems and makes Latin American economies more prone to credit instability, even after the implementation of financial liberalization (Caballero 2000; Mas 1995); (ii) The structure of balance sheets of Latin American firms

2.2. *Patterns of deforestation in Latin America*

Deforestation rates in Latin American countries differ sharply across time and space (tables 2 and 3 in statistical appendix).⁵ Deforestation rates are high during the 50s, the 60s and the 70s, then drop in the 80s and increase sharply since the second half of the 90s. High rates of deforestation in the 50s and 60s did not raise particular concern in this post-war period which was characterised by the overwhelming goal of economic growth and great optimism (Edwards 1995). Large parts of primary forests disappeared with for instance the destruction of the Atlantic rainforest in Brazil due to coffee plantations expansions (Thorp 1998). Import substitution strategies (ISS) have been conducted in the 50s and the 60s in many Latin American countries. Although they gave a non negligible importance to mining and forest products industries (Randall 1997), it is considered that they reduced natural resource use by promoting industrial sectors. Nevertheless, despite the ISS' anti-agricultural bias, it is alleged that ISS gave less incentives to conserve natural resources. For instance, land was under-utilized in large agricultural establishments of which lands may have encroached on forested areas (Southgate & Whitaker 1992).

Highest deforestation rates are found in Central American countries: five Central American countries⁶ are among the seven that exhibit an average deforestation rate greater than 1% over the whole period; in 2001, half of the 1961 forest cover remains in Central American (Carr et al. 2006). Costa Rica experienced for instance the highest deforestation rates from the fifties to the beginning of the eighties, illustrating the predominant views of economic development in Latin America: agri-business exportation sector, import substitution strategy until the structural adjustment programs which stopped deforestation in the early 80s. Since then, forest preservation initiatives have reduced the pressure on forests (de Camino et al. 2000). The same story

raises their vulnerability to exchange rate shocks through the currency mismatch mechanism and this vulnerability is transferred to the banking system; (iii) The Latin American countries have hardly implemented countercyclical monetary policies, either due to the "original sin" effect in floating exchange rates (Eichengreen & Hausmann 2005) or due to politicians preferences in fixed exchange rate regimes.

⁵ Deforestation data are drawn from quinquennial FAO censuses implemented since 1948 to 2005. Annual deforestation rates are computed on 5-years periods (except for the first period). Among 24 Latin American countries for which forest coverage statistics are available, 4 countries are dropped (Argentina, Chile, Surinam and Uruguay) since they exhibit an afforestation profile throughout the period. Therefore the sample includes 4 Caribbean, 8 Central American and 8 South American countries.

⁶ Namely El Salvador, Costa-Rica, Honduras, Nicaragua, and Panama; other countries are Jamaica and Paraguay.

is at work in Nicaragua and Honduras which have considerably developed their beef exports. The proximity of the United States has stimulated the demand for agricultural and cattle products. The Latin American Agri-business Development (LAAD) Corporation is deemed to have contributed to the process when pouring large amounts of capital into Central American countries in the 60s.

Even if the two phenomenons described above (credit instability and high deforestation) exhibit no clear-cut correlation in Latin America over the last decades (see Table 3 and Table 4 in the statistical appendix) there are basic mechanisms through which credit instability might affect deforestation.

3. *How credit instability might affect deforestation?*

3.1. Basic assumptions

The link between credit instability and deforestation relies on the following mechanism: credit cycles induce variations of the opportunity cost of capital, thus leading to factor reallocations between sectors (according to their access to credit). Due to the irreversibility of deforestation, these reallocations will almost always lead to net deforestation, whatever the expanding sector. This result relies on the fact that economy is made up of several sectors that use different production technologies, i.e. a different combination of labour, capital and land, the latter being increased by deforestation. Let us now be more specific on the concepts and the assumptions made.

- (i) The key variable is the opportunity cost of capital (r), that not only encompasses the interest rate charged by the lender, but also costs induced by credit access (network building, guarantees, etc.) and the costs generated by capital and land holdings (supervision, monitoring, etc.). This non-monetary part of the opportunity cost of capital may be important in a credit rationing context. It is determined by the liquidity of financial institutions (thus by domestic monetary policy stance and the liquidity on international financial markets), and the risk on lending activities (thus by political instability, security of property rights, etc...). Therefore domestic monetary policy is only one of the factors of the opportunity cost of capital variations.
- (ii) In Latin America where information asymmetries between lenders and borrowers and hence credit rationing (Stiglitz & Weiss 1981) are arguably stronger

than in industrialized countries, the equilibrium quantity of credit is mainly determined by supply shifts. In other words, a credit crunch means a rise of the opportunity cost of capital (and conversely a credit boom means a drop of this cost);

- (iii) The behaviour of agents involved in the deforestation process in Latin America is assumed to be mainly driven by short-term considerations. Admittedly the use of any resource implies a trade-off between short-term and long-term benefits and costs. Nevertheless, land property rights insecurity in Latin American countries justifies (among other pieces of explanation) to focus on short-term mechanisms. Agents are restrained from considering forest as a natural asset which generates inter-temporal income flows and are prompted to favour immediate returns.
- (iv) The deforestation process is irreversible. Indeed, when an economic activity that consumes forest area decreases, the land set aside may not be fully reforested (at best partially reforested). The irreversibility arises from the non renewable character of the primary forests. Conversely, when an economic activity that consumes forest area increases, it will only partially re-use the fallows, since costs of reutilization may be higher than deforestation ones.

3.2. Deforestation modelling

Our model derives from for instance Barbier where deforestation is the result of land conversion by a profit maximising agent (Barbier 2007, p.212). The main difference of our model consists in introducing two sectors to catch the dual character of the agricultural sector in Latin American countries.⁷ The first sector is a “labour intensive” sector (LI) and the second one is a “capital intensive” sector (KI). The LI sector has a production function G which uses land H^G and labour L^G only. The LI sector barely access credit markets, which impedes capital accumulation. Despite all these constraints, economic agents are deemed to maximise their profits according to the “poor but efficient” hypothesis (Schulz 1964). Population pressure reduces fallow periods and generates deep advances in forested areas (Metzger 2003). The production function F in the KI sector, depends on three production factors: land H^F , labour L^F that equals $L-L^G$, and capital K . The KI sector pictures agricultural and or livestock-keeping activities that

⁷ Many researchers emphasised the dual character of Latin American agriculture (Dorner & Quiros 1973; Horowitz 1996)

may have an access to formal and or international agricultural markets. The KI sector output is sold at price p ; the *numéraire* is the output price of the LI sector. To sum up, the LI sector has no access to credit and the KI sector is subject to sharp variations in the opportunity cost of capital.

Both production functions have positive and decreasing marginal productivities, and non increasing returns to scale. They satisfy Inada conditions and allow factors substitutions. In addition, cross second derivatives are non negative. Labour moves freely from one sector to another one with a constant total supply L . Both sectors share a common wage w that induces labour allocation in the economy. Capital use is determined by its opportunity cost r which includes a rental rate and an agency cost. Land is a specific factor of which rental prices are h^G and h^F in the LI and KI sectors respectively. h^G and h^F represents clearing marginal costs, opportunity costs generated by forest depletion, exclusion costs or market prices. Land specificity derives from differences in localizations, soil qualities, and legal statutes.

Tropical deforestation is mainly an irreversible process which is the result of agricultural land encroachments from both sectors. Increases in H^F or H^G are defined as deforestation (Barbier & Burgess 2001), whereas decreases in H^F or H^G are increases of fallow lands or degraded forests. Nevertheless, it is possible that a small portion of fallow lands turn over to forest in the LI. Indeed, secondary forestation is usual in areas where forests have been degraded by slash-and-burn agriculture. Forest re-growing is more difficult in the KI sector where forest clearing is deemed to be more complete. Fallow lands provide several products and services and allow raising cattle which increases the value of land (Fujisaka et al. 1996). It may be thus profitable even in the KI sector, not to reduce them under increasing demand for agricultural land.

The profit maximization by the representative agent is made upon H^F , H^G , L^G and K :

$$\max_{L^G, K, H^G, H^F} \pi \equiv G(L^G, H^G) + pF(L - L^G, H^F, K) - wL - rK - h^G(H^G)H^G - h^F(H^F)H^F$$

h^G and h^F are increasing and convex functions of H^G and H^F respectively: $h_H^G > 0$, $h_{HH}^G > 0$, $h_H^F > 0$, $h_{HH}^F > 0$.

Subscripts indicate first derivatives and stars the optimum values in the first order necessary conditions:

$$\frac{\partial \pi^*}{\partial L^G} = 0 \Leftrightarrow G_L(L^{G^*}, H^{G^*}) - pF_L(L - L^{G^*}, H^{F^*}, K^*) = 0 \quad (1)$$

$$\frac{\partial \pi^*}{\partial K} = 0 \Leftrightarrow pF_K(L - L^{G^*}, H^{F^*}, K^*) - r = 0 \quad (2)$$

$$\frac{\partial \pi^*}{\partial H^G} = 0 \Leftrightarrow G_H(L^{G^*}, H^{G^*}) - h^G(H^{G^*}) - h_H^{G^*}(H^{G^*})H^{G^*} = 0 \quad (3)$$

$$\frac{\partial \pi^*}{\partial H^F} = 0 \Leftrightarrow pF_H(L - L^{G^*}, H^{F^*}, K^*) - h^F(H^{F^*}) - h_H^{F^*}(H^{F^*})H^{F^*} = 0 \quad (4)$$

Provided the sufficient order condition holds, the optimal choice functions are implicit functions of the parameters and especially of r . The comparative static exercise is interpreted as the simulation of a credit crunch (boom) when the opportunity cost of capita r is increases (decreases). Taking the properties of production functions into account, the comparative statics results are the following:

$$\frac{dL^G}{dr} > 0; \frac{dH^G}{dr} > 0; \text{sign } \frac{dK}{dr} \text{ ambiguous; } \text{sign } \frac{dH^F}{dr} \text{ ambiguous}$$

When a credit boom ($dr < 0$) occurs, production factors are reallocated towards the KI sector of which production costs relatively decrease with respect to the LI sector. Since there are no barriers to labour moving between the two sectors, L^G decreases. Assuming that second derivatives of production functions are strongly negative, it can be shown that K and H^F increase when r decreases.⁸ The total effect of the credit boom ($dr < 0$) on deforestation is thus positive in as much as waste lands in the LI sector cannot compensate forest clearing in the KI sector. This case is illustrative of the recent agricultural boom in the Amazon by farmers who need credit to buy fertilizers, pesticides and seed as well to build capital equipments and to finally address increasing demand for soy, corn, cotton or sugar cane.

A credit crunch represented by an increase in r induces deforestation as well. An expansion of the LI sector is generated, which is also forest consuming: when farmers and agricultural households cannot rely on capital, they also move to land clearing which is often labour intensive.

⁸ See in the mathematical appendix the derivation of the second order conditions and the comparative static exercise. It is worth noticing that introducing a constraint on K does not qualitatively change the comparative static results on r .

Deforestation is thus generated whatever the change in r . Deforestation is driven by labour-intensive agriculture during credit crunch episodes whereas it is driven by capital-intensive agriculture during credit boom episodes. The detrimental effect of a credit boom and crunches on deforestation is at work in a dual agricultural model building on the idea of specific production factors and the irreversible character of land clearing. Moreover, if credit instability is defined as successive increases and decreases of the opportunity cost of capital, then the model predicts that credit instability produces deforestation.

4. *Application to Latin American countries*

Data and econometric specification are described first, then the econometric results are presented and discussed.

4.1. Data and econometric specification

The dependant variable is the rate of deforestation from FAO censuses and databases (FAO 2006; FAO 2005; FAO 2007) computed over five years periods to mitigate annual and random measurement errors in deforestation data. All explanatory variables are also five years averages which allow taking into account delays in adjustment processes and dampening short term influences in the deforestation process.⁹

In Latin American countries the variation of the opportunity cost of capital is better caught by the real credit growth rate than by interest rates variations, since credit rationing is marked and interest rates were largely managed until the eighties (Barajas & Steiner 2002a). Therefore credit instability is proxied by the standard error of the real credit growth rate

We take into account three groups of control variables.

- (i) Deforestation may depend on both credit instability and credit path as well; this justifies controlling for the real credit growth rate.
- (ii) Deforestation is also determined by a set of structural factors. This set includes GDP per capita and squared GDP per capita (both expressed in logarithms) according

⁹ Except for the first period, 1948-1958 and the last one: 1999-2005

to the Environmental Kuznets Curve assumption. Existing studies provide ambiguous results: Bhattarai and Hammig (Bhattarai & Hammig 2001) or Culas (Culas 2007) do not reject the hypothesis whereas Meyer, Van Kooten and Wang do (Meyer et al. 2003). Barbier's results (Barbier 2004a) on a Latin American sample depend on the control variables. Trade openness (measured as exports and imports over GDP) can hasten deforestation by promoting agricultural exports, commercial logging or natural resource extraction (Ferreira 2004). Population density (expressed in logs) could also affect deforestation but the net impact is ambiguous. Indeed, on the one hand population density may accelerate the conversion of forest into arable lands and may increase the demand for fuel wood (Cropper & Griffiths 1994). On the other hand, it can reduce deforestation by enhancing the demand for forest products (Foster & Rosenzweig 2003). At last, a better institutional quality could discourage clearing (Bhattarai & Hammig 2001). It is here measured by a composite indicator of Democracy and Autocracy (Marshall & Jaggers 2009).¹⁰

(iii) The third group of variables aims at capturing the effects of macroeconomic policy. The first variable concerns relative price variations, *i.e.* the bilateral real exchange rate with the United States.¹¹ Adopting this variable is justified by the concentration of Latin American countries trade with the USA. Moreover, most prices of primary commodities exported by these countries are denominated in US dollars. The logarithm of the real exchange rate controls for the competitiveness of the export sector. Real depreciation is expected to fuel deforestation (Arcand et al. 2008). The real GDP growth rate and the standard error of the real GDP growth rate allow disentangling the effects of credit from those of economic activity.

The estimations are made using country-specific and time-specific fixed-effects.¹² They mimic the influence of omitted variables constant over time (, country

¹⁰ This variable catches the regime authority spectrum on a 21-point scale ranging from -10 (hereditary monarchy) to +10 (consolidated democracy).

¹¹ The real exchange rate is calculated as follows : $RER_{i,t}^{1990} = INER_{S/i,t}^{1990} \cdot P_{USA,t}^{1990} / P_{i,t}^{1990}$ where $INER_{S/i,t}^{1990}$ is an index of the value of one US dollar expressed in national currency units using 1990 as a base year, and $P_{USA,t}^{1990}$ and $P_{i,t}^{1990}$ are consumer price indexes, respectively in the United States and in country (i). A rise in the real exchange rate index thus corresponds to a real depreciation.

¹² A simple and preliminary decomposition of the deforestation process shows that strong idiosyncratic factors are at work. This can be shown by estimating a regression equation of average annual deforestation rates on periods and country fixed effects. The magnitude of idiosyncratic factors may be

characteristics, *i.e.* geographical factors such as landlockness, cultural factors, etc.) and of omitted variables common to the countries (agricultural commodities and forest products prices, energy prices, world interest rates...).

4.2. Results

Insert Table 1

Equations 1 to 3 are estimated with the panel least squares method. An Environmental Kuznets Curve is suggested: deforestation increases with the level of development when GDP per capita is smaller than 1800\$, then decreases beyond this threshold.—Population density and trade openness variables are both insignificant (equation 1) and are dropped in the following equations. Besides, Arcand et al. (2008) found similar results and suggest that the impact of these variables could operate through relative prices. The institutional quality index does not affect deforestation (equation 1) and it is also dropped. The impact of this variable might be caught by country fixed effects since institutional quality hardly change over time.

As regards the impact of macroeconomic policies, the real GDP growth rate and the standard error of the real GDP growth rate are both insignificant (equations 1 and 2). The real exchange rate is only marginally significant with a positive sign as expected.

The credit instability measured as the standard error of the real credit growth rate positively affects deforestation rates (equations 1, 2 and 3) when controlling by the real credit growth rate.

However, a critique for the results concerns the assumption of orthogonality between credit instability and deforestation. Indeed, this assumption may be violated on two grounds. First, the credit instability is only a proxy of the opportunity cost of capital instability and hence may be measured with an error (the attenuation bias). Second, one may question the exogeneity of credit instability because of missing variables.¹³ To deal

inferred from the calculation of $1-R^2$ of the regression. The latter is 0.82 which must be interpreted as an upper bound on the variance of independent idiosyncratic factors since the total variability may also be the result of measurement errors.

¹³ However, it is quite difficult to suspect a double causality between deforestation and credit instability.

with these problems, we draw on the panel two stages least squares (PTOLS) estimation method (equations 4 and 5).

We split instrumental variables into two groups. First, the credit instability is instrumented by the sole standard error of the real base money growth rate (equation 4). Second the credit instability is instrumented both by the standard error of the real base money growth rate and by the political regime durability computed by the Polity IV program (equation 5).¹⁴ On the one hand, we assume that the two instruments are correlated with credit instability. Base money instability generates credit instability through the money multiplier and the regime durability dampens the monetary upheavals. On the other hand the two instruments are assumed to be not correlated with the error term. Indeed, although the standard error of the real money base growth rate measures with error the opportunity costs of capital instability, this error is assumed to be orthogonal with the measurement error of the credit instability. Moreover, it is hard to suspect an impact of the regime durability on deforestation beyond the indirect effect through the credit instability. It can be argued that the regime durability is linked with the institutional quality which could affect directly deforestation. Nevertheless the indices of institutional quality are never significant in our equations. Two tests support the instrumentation strategy. According to Stock et al. (2002, p.522) instruments are not weak since the first stage F statistics are superior to 10. Moreover, the Sargan test does not reject the null hypothesis of the over-identification restrictions in equation (5).

The marginal impact of credit instability remains positive in equations 4 and 5. The coefficients are significantly higher which can be explained by the attenuation bias in the PLS estimations. When credit instability is multiplied by 2, deforestation rate gains 0.09 points (i.e. approximately 1/3 of the mean deforestation rate in the sample).

Finally, we consider lagged dependent variable (equation 6) or initial forest area (in logarithms, equation 7) to test the impact of relative scarcity of forest resources (convergence hypothesis in the forest cover). Using dummy variables to catch country effects in a model which includes a dynamic specification can bias PLS estimates. In such cases, the generalized method of moments (GMM) estimator is widely used. Blundell &

¹⁴ The regime durability is defined as the number of years since the most recent regime change or the end of transition period defined by the lack of stable political institutions.

Bond (1998) propose a system GMM procedure combining the equations in first differences and the equations in level and allowing for the use of lagged differences and lagged levels of the explanatory variables as instruments. Two external instruments are added: the money base instability and the regime durability. The GMM estimations control for the endogeneity of initial forest area and credit instability.¹⁵ The Hansen / Sargan tests of over identification do not invalidate the instrumentation strategy.

These dynamic specifications do not improve the quality of the estimations: lagged deforestation rate (equation 6) and lagged forest area (equation 7) are not significant and the marginal impact of credit instability does not change significantly.

5. *Concluding remarks*

Peculiar characteristics of Latin American countries motivate present investigations on the link between deforestation and credit instability. Indeed many Latin American countries are land abundant, exhibit rapid deforestation rates and often experience the succession of credit boom and crunches episodes. This paper provides a theoretical explanation and empirical investigations of this phenomenon. Econometric tests are conducted on the 1948-2005 period on an exhaustive sample of Latin American countries. The deforestation database is derived from a compilation of censuses carried out by the FAO. The main output of the paper is to evidence that credit instability fuels deforestation. The results are robust to the introduction of usual control variables.

This paper confirms the role of short-term macroeconomic policies on deforestation and thus shows that the macroeconomic instability may have broader negative effects than that is usually acknowledged. It is not only detrimental to growth and welfare, but has also a negative effect on the environment through an increase in deforestation. Therefore the effectiveness of usual instruments of environmental policies (taxation, norms and property rights) may be enhanced by macroeconomic policies aiming at downsizing credit cycles.

¹⁵ The other variables are considered as strictly exogenous.

Tables and Figures

Table 1. Determinants of deforestation in Latin America (1948-2005)

Methods of estimation	Panel Least Squares			Panel Two-Stages Least Squares		Dynamic panel-data estimation, one-step system GMM	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
<i>Structural factors</i>							
Real GDP per capita (Log)	0.12 (1.77)*	0.11 (1.67)*	0.12 (1.84)*	0.12 (1.61)*	0.13 (1.61)*	0.07 (1.86)*	0.10 (2.08)**
Squared real GDP per capita (Log)	-8.2 10 ⁻³ (-1.78)*	-7.6 10 ⁻³ (-1.68)*	-8.0 10 ⁻³ (-1.83)*	-8.0 10 ⁻³ (-1.62)*	-8.3 10 ⁻³ (-1.61)*	-4.7 10 ⁻³ (-1.91)*	-6.8 10 ⁻³ (2.09)**
Population density (Log)	-0.01 (-0.20)						
Trade openness (Log)	6.3 10 ⁻³ (1.11)						
Institutional quality	2.7 10 ⁻⁴ (1.00)						
<i>Macroeconomic policies</i>							
Real exchange rate (Log)	6.3 10 ⁻³ (1.82)*	4.110 ⁻³ (1.19)	3.7 10 ⁻³ (1.66)*	2.1 10 ⁻³ (0.75)	1.8 10 ⁻³ (0.62)	-2.6 10 ⁻⁴ (-0.13)	1.9 10 ⁻³ (0.66)
Real Credit growth rate	-3.7 10 ⁻⁴ (-0.12)	3.0 10 ⁻⁴ (0.11)	-2.2 10 ⁻⁴ (-0.09)	4.6 10 ⁻³ (0.75)	6.4 10 ⁻³ (0.99)	5.6 10 ⁻³ (0.99)	3.0 10 ⁻³ (0.78)
Standard error of the Real Credit growth rate	8.5 10 ⁻³ (2.37)**	8.4 10 ⁻³ (2.48)**	8.0 10 ⁻³ (2.51)***	0.02 (1.62)*	0.03 (1.88)**	0.02 (1.69)*	.01 (1.80)*
Real GDP growth rate	-5.8 10 ⁻³ (-0.25)	-0.01 (-0.56)					
Standard error of the Real GDP growth rate	5.410 ⁻³ (0.28)	6.410 ⁻³ (0.36)					
<i>Dynamic panel variables</i>							
Lagged D Log forest						0.11 (0.71)	
Lagged Log forest							2.2 10 ⁻³ (1.35)
R2 adjusted	0.17	0.20	0.23	0.26	0.22		
Observations	157	163	166	151	147	137	145
Periods included	10	10	10	9	9	9	9
Countries included	18	19	19	18	17	17	17
<i>Exclusion restriction tests</i>							
Stock Yogo First stage F				17.44	31.24		
Sargan Overidentification test Chi 2 (p value)					1.40 (0.76)	3.47 (0.48)	3.53 (0.47)
Hansen / Sargan difference Overidentification test Chi 2 (p value)						0.91 (0.63)	1.16 (0.56)

Dependent variable: D log forest. Robust t statistics in parentheses * significant at 10%, ** significant at 5%; *** significant at 1%.

Statistical appendix

Table 2. Forest data sources (1948 -2005)

Survey	Survey Year	References	Data
FOREST RESOURCES OF THE WORLD	1948	Unasylya, Revue internationale des forêts et des produits forestiers, Vol. 2(4), juillet-août, 1948	1948
WORLD FOREST INVENTORY	1958	FAO. 1960. <i>World forest inventory 1958</i> - the third in the quinquennial series compiled by the Forestry and Forest Products Division of FAO. Rome.	1958
WORLD FOREST INVENTORY	1963	FAO. 1966. <i>World forest inventory 1963</i> , Rome	1963
FAO stat	Various issues	FAO stat. CD-rom version 1998 (available between 1989 and 1994 on the FAO website http://faostat.fao.org/site/418/DesktopDefault.aspx?PageID=418)	1968, 1973, 1978, 1983, 1988, 1993
FOREST RESOURCES ASSESSMENT - Interim report	1990	FAO 1993. <i>Forest Resources Assessment 1990 - Tropical countries</i> , FAO Forestry Paper No. 112. Rome.	1998
FOREST RESOURCES ASSESSMENT - Interim report	1995	FAO. 1997, <i>State of the World's Forests</i> , Rome	1998
FOREST RESOURCES ASSESSMENT	2005	FAO. 2005, <i>Global Forest Resources Assessment 2005: Progress towards sustainable forest management</i> , FAO Forestry Paper 147, Rome (or www.fao.org/forestry/site/fra2005/fr)	2005

Note: In order to keep a five-year frequency until the last period, 1998 is calculated by interpolating the forest cover between 1995 (or 1990, depending on availability and consistency of data) and 2000

Table 3. Average annual rates of deforestation in Latin American countries 1948 - 2005, percentages

		48-57	58-63	64-68	69-73	74-78	79-83	84-88	89-93	94-98	99-05	
Belize	CA	1,51	0,28	0,13	0,70	0,74	0,00	0,00	0,00	0,00	0,00	0,34
Costa-Rica	CA		3,79	2,52	2,88	3,37	4,20	0,61	-0,26	1,01	0,33	2,05
El Salvador	CA		4,22	2,04	1,11	2,67	4,30	2,96	0,00	1,88	2,22	2,38
Guatemala	CA	2,93	0,15	0,57	0,59	1,23	0,91	-2,13	-0,83	1,56	1,79	0,68
Honduras	CA		2,72	0,00	0,00	0,00	0,00	0,00	0,00	3,71	4,32	1,19
Mexico	CA		-0,10	0,94	0,99	1,04	1,38	-0,75	-0,29	0,68	0,63	0,50
Nicaragua	CA		0,70	1,84	2,03	2,26	2,50	2,80	2,33	1,44	1,71	1,96
Panama	CA		3,11	0,65	0,67	0,69	1,71	2,65	0,79	0,19	0,13	1,18
Dominican Rep	CAR		0,12	0,30	0,31	0,31	0,31	0,32	0,62	0,00	0,00	0,25
Haiti	CAR		0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,91	1,01	0,21
Jamaica	CAR		11,26	0,48	0,49	0,50	0,51	0,53	0,21	0,16	0,16	1,59
Trinidad & Tobago	CAR	2,60	0,51	0,41	0,42	0,43	0,43	0,44	-1,14	0,40	0,32	0,48
Bolivia	SA		0,28	0,42	0,43	-0,19	0,00	0,00	0,00	0,59	0,63	0,24
Brazil	SA	1,50	0,24	0,34	0,39	0,44	-1,11	-0,39	0,21	0,60	0,74	0,30
Colombia	SA	0,37	3,39	0,15	0,68	0,36	0,00	0,18	0,56	-0,22	-0,03	0,54
Ecuador	SA		-3,64	1,27	1,23	0,19	0,00	0,00	-0,13	2,00	2,34	0,36
Guyana	SA	0,01	-0,08	0,00	0,00	1,55	0,55	0,00	-0,16	0,11	0,04	0,20
Paraguay	SA		-0,52	0,23	0,24	0,24	1,93	4,46	2,98	0,23	0,88	1,19
Peru	SA		1,38	0,00	0,00	0,00	0,00	0,00	0,01	0,17	0,19	0,19
Venezuela	SA		3,32	0,77	0,81	0,84	-1,80	-3,19	-0,89	0,39	0,56	0,09
		1,49	1,56	0,65	0,70	0,83	0,79	0,42	0,20	0,79	0,90	0,80

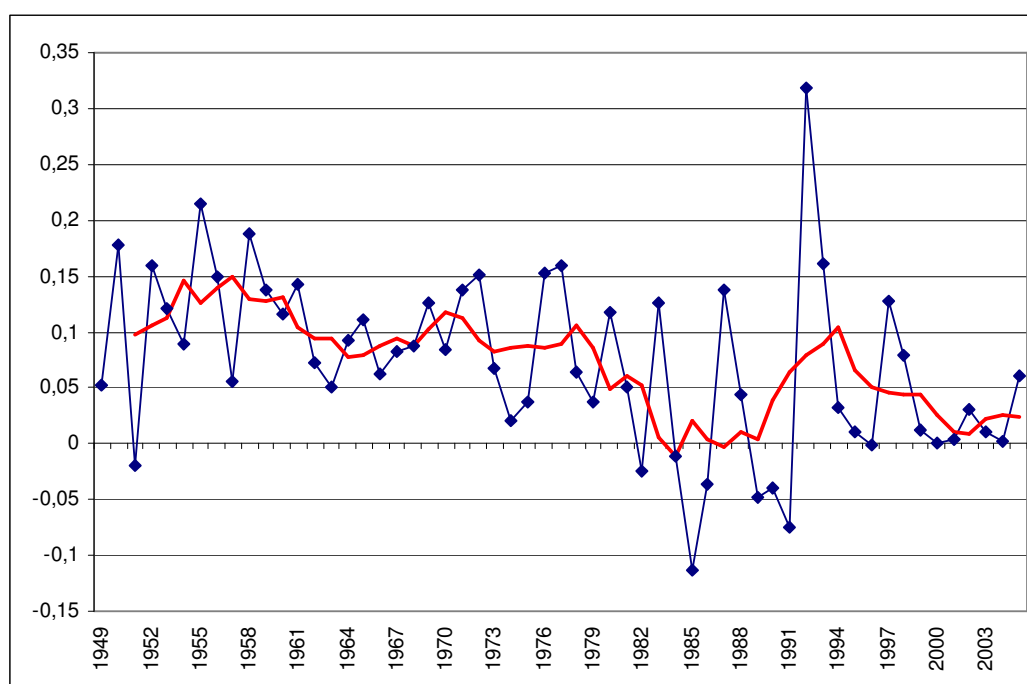
Source: Authors' calculations from several issues of FAO censuses CA: Central American country, CAR: Caribbean country, SA: South American Country

Table 4. Credit growth rate standard errors in Latin American countries 1948 – 2005

		48-58	59-63	64-68	69-73	74-78	79-83	84-88	89-93	94-98	99-05	
Belize	CA							0,09	0,13	0,09	0,13	0,11
Costa-Rica	CA	0,11	0,12	0,05	0,14	0,11	0,31	0,07	0,10	0,26	0,07	0,13
El Salvador	CA	0,19	0,11	0,07	0,06	0,07	0,12	0,24	0,19	0,12	0,10	0,13
Guatemala	CA	0,17	0,08	0,07	0,09	0,05	0,08	0,12	0,07	0,09	0,08	0,09
Honduras	CA	0,25	0,10	0,11	0,11	0,05	0,06	0,05	0,13	0,10	0,12	0,11
Mexico	CA	0,10	0,03	0,03	0,04	0,08	0,22	0,18	0,05	0,28	0,03	0,11
Nicaragua	CA					0,08	0,25	0,51	1,88	0,11	0,03	0,48
Panama	CA	0,12	0,11	0,07	0,04	0,10	0,06	0,10	0,13	0,07	0,08	0,09
Dominican Rep	CAR	0,26	0,13	0,08	0,03	0,12	0,01	0,16	0,17	0,09	0,14	0,12
Haiti	CAR		0,05	0,09	0,06	0,02	0,07	0,13	0,10	0,05	0,15	0,08
Jamaica	CAR		0,35	0,12	0,12	0,14	0,17	0,10	0,28	0,17	0,32	0,20
Trinidad & Tobago	CAR		0,38	0,08	0,08	1,18	1,33	0,10	0,07	0,15	0,07	0,38
Bolivia	SA	0,42	0,04	0,05	0,09	0,31	0,49	1,25	0,14	0,13	0,05	0,30
Brazil	SA	0,06	0,10	0,17	0,11	0,13	0,12	0,40	0,39	0,34	0,09	0,19
Colombia	SA	0,12	0,14	0,08	0,04	0,10	0,13	0,10	0,15	0,08	0,04	0,10
Ecuador	SA	0,11	0,10	0,08	0,11	0,06	0,22	0,13	0,67	0,19	0,23	0,19
Guyana	SA										0,07	0,07
Paraguay	SA		0,08	0,09	0,04	0,10	0,13	0,06	0,34	0,06	0,15	0,12
Peru	SA	0,06	0,02	0,09	0,09	0,08	0,21	0,24	0,32	0,27	0,10	0,15
Venezuela	SA	0,49	0,16	0,07	0,06	0,15	0,07	0,10	0,21	0,23	0,22	0,18
		0,190	0,122	0,082	0,078	0,164	0,225	0,218	0,291	0,152	0,113	0,16

Source: Authors' calculations from IFS.

Figure 1. Annual growth rates country averages of real credit (five-year moving average in bold)



Source: Author's calculations from IFS

Mathematical appendix

* The Hessian matrix evaluated at the maximum is the following:

$$D^2\pi^* \equiv \begin{pmatrix} G_{LL}^* + pF_{LL}^* & -pF_{LK}^* & G_{LH}^* & -pF_{LH}^* \\ -pF_{KL}^* & pF_{KK}^* & 0 & pF_{KH}^* \\ G_{HL}^* & 0 & \tilde{G}_{HH}^* & 0 \\ -pF_{HL}^* & pF_{HK}^* & 0 & p\tilde{F}_{HH}^* \end{pmatrix} \text{ with } \tilde{G}_{HH} \equiv G_{HH} - (2h_H^G + H^G h_{HH}^G) < 0 \text{ and } \\ \tilde{F}_{HH} \equiv F_{HH} - \frac{1}{p}(2h_H^F + H^F h_{HH}^F) < 0$$

The sufficient second order condition for a maximum implies that the Hessian must be negative definite. That means in particular that $|D^2\pi^*| > 0$. The optimal choice functions are implicit functions of the parameters and especially of r . The comparative static exercise on r allows simulating credit crunch (boom) when dr is positive (negative). When totally differentiating the first order conditions, the system of equations of four unknowns is the following:

$$\begin{pmatrix} G_{LL}^* + pF_{LL}^* & -pF_{LK}^* & G_{LH}^* & -pF_{LH}^* \\ -pF_{KL}^* & pF_{KK}^* & 0 & pF_{KH}^* \\ G_{HL}^* & 0 & \tilde{G}_{HH}^* & 0 \\ -pF_{HL}^* & pF_{HK}^* & 0 & p\tilde{F}_{HH}^* \end{pmatrix} \begin{pmatrix} dL^G/dr \\ dK/dr \\ dH^G/dr \\ dH^F/dr \end{pmatrix} = \begin{pmatrix} 0 \\ 1 \\ 0 \\ 0 \end{pmatrix}$$

The Cramer's rule allows deriving the optimal responses to changes dr (stars omitted) taking into account the sign of the Hessian and the hypotheses on the production functions:

$$\text{sign} \frac{dL^G}{dr} = -\text{sign}(-p^2 \tilde{G}_{HH} \tilde{F}_{HH} F_{LK} + p^2 \tilde{G}_{HH} F_{LK} F_{LH}) \text{ which is positive}$$

$$\text{sign} \frac{dH^G}{dr} = -\text{sign}(-p^2 G_{HL} F_{HK} F_{LH} + p^2 G_{HL} F_{LK} \tilde{F}_{HH}) \text{ which is positive}$$

$$\text{sign} \frac{dK}{dr} = -\text{sign}((G_{LL} + pF_{LL}) \tilde{G}_{HH} p\tilde{F}_{HH} - (G_{HL})^2 p\tilde{F}_{HH} - p^2 \tilde{G}_{HH} (F_{HL})^2) \text{ which is ambiguous}$$

$$\text{sign} \frac{dH^F}{dr} = -\text{sign}(-(G_{LL} + pF_{LL}) \tilde{G}_{HH} pF_{HK} + (G_{HL})^2 pF_{HK} + p^2 \tilde{G}_{HH} F_{HL} F_{LK}) \text{ which is ambiguous}$$

$\frac{dL^G}{dr} > 0$ and $\frac{dH^G}{dr} > 0$. An increase in r unambiguously increases the output in the LI sector. The latter is obtained by labour and land inputs increases. According to equation (3), H^G and L^G move the same way. Indeed, an increase in labour inputs L^G induces an increase of the marginal productivity of land ($G_{HL}^* > 0$): the optimum is restored by an increase in H^G ($G_{HH}^* < 0$ and / or $h_H^G > 0$ and / or $h_{HH}^G > 0$).

The opportunity cost of capital r has an ambiguous effect on land inputs and capital in the KI sector since the effect of an increase of r on F_K may be compensated by a

modification in the combination of three KI inputs: labour, land or capital. Additional hypotheses must be put forward to solve this ambiguous effect and derive instead a negative effect of r on K and H^F

$\frac{dK}{dr} < 0$. If $G_{LL}^* + pF_{LL}^*$ is strongly negative then labour reallocation towards the LI sector induces a sharp decrease in the marginal profitability of labour $G_L + pF_L$ becomes negative. The optimum can be restored either by an increase in H^G ($G_{LH}^* > 0$), or a decrease in H^F ($F_{LH}^* > 0$) or a decrease in K ($F_{LK}^* > 0$). The first two ones are insufficient if cross derivatives G_{LH}^* and F_{LH}^* are negligible. Then, a decrease in K restores the optimum (equation 1).

$\frac{dH^F}{dr} < 0$. According to equation (4), a decrease in K induces a decrease in the marginal productivity of land in the KI sector ($F_{HK}^* > 0$). This effect is magnified by a decrease in labour inputs in the KI sector ($F_{HL}^* > 0$). The optimum is restored by a decrease in H^F ($F_{HH}^* < 0$ and / or $h_H^F > 0$ and / or $h_{HH}^F > 0$).

Since labour, capital, and land inputs decrease in the KI sector, the output is negatively affected by a credit crunch.

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