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The Effects of Governmental Spending on Deforestation and CO_2 Related Emissions

By

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ABSTRACT. This paper examines the effect of changes in government spending level and composition on deforestation and related carbon dioxide emissions. Our theoretical model shows an unintended consequence from increased government spending and widening social safety nets during times of recession: there is an increase in deforestation and carbon dioxide emissions from land use change. Our empirical tests show that an increase in total government spending significantly increases forest land clearing for agricultural production in the short run leading to more carbon dioxide emissions. However, there is no long-run statistically significant effect on the steady-state forest cover and carbon dioxide emissions. (JEL H11, H20, O13, Q23)

I. INTRODUCTION

The recent global recession has affected the level and composition of public expenditures in developing countries. Historically, developing countries tended towards procyclical spending where spending is cut during recessions but increased during expansions. However, over the past decade, fiscal policies in emerging markets with good quality institutions shifted towards countercyclical spending where spending rises during recessions to counter the effects of the business cycle (Frankel et al. 2011). Aside from changes in spending levels, the composition of fiscal spending also changes during recessions as more social safety nets are put in place (Williams et al. 2012).

Recent empirical work showed that changes in the level and composition of fiscal spending significantly affect pollution levels (Bernauer and Koubi 2006; Halkos and Paizanos 2013; López, Galinato, and Islam 2011; López and Palacios 2014). Most of the pollution analyzed occurs as a by-product during the production process such as sulfur dioxide and lead. We are only aware of one study that linked the effect of fiscal spending on carbon dioxide (Halkos and Paizanos 2013), a leading contributor to greenhouse gas emissions, but this study also focuses on carbon dioxide through the production process. Given that the main contributors of greenhouse gas emissions in the developing world is land use change (Crutzen and Andreae 1990; Naughton-Treves 2004), it is surprising that the connection between fiscal policy spending on greenhouse gas emissions through deforestation has not yet been systematically analyzed.

This article fills this gap in the literature by determining the long-run and short-run effects of fiscal policies on forest cover and deforestation-induced carbon dioxide (CO_2) emissions. We develop a dynamic model that links the effect of the level and composition of fiscal spending on the transition and steady-state paths of agricultural land clearing in forested areas. This model allows us to understand the mechanism relating fiscal policies and CO_2 emissions due to deforestation in developing countries. Using the theoretical results, we empirically measure the effect of changes in public expenditure size and composition on CO_2 emissions in the short run and long run. We contribute to the growing literature on fiscal policy and environmental quality by showing the differences by which government spending affect deforestation-induced CO_2 emissions as opposed to CO_2 emissions from other sectors of the economy. Our results have significant policy implications because we are able to predict the potential effects of fiscal policies during economic downturns on the environment which may lead to policy recommendations that ameliorate such effects.

There are direct or underlying factors of deforestation where the former refer to factors that immediately cause deforestation while the latter are those that influence the severity of direct factors. In developing countries, one of the most common direct factors is the clearing of forest land for agricultural production (López 1997).[1] Public expenditures are an example of underlying factors that affect forest land conversion.

To understand how government spending affects the direct factors that influence deforestation, we focus on the role of different types of government spending. The composition of public expenditure can be delineated based on a taxonomy proposed by López and Galinato (2007) that classifies two types of spending based on their effect on market efficiency. The first type is called "expenditures on public goods" which are government expenditures that alleviate market failure. Spending on health and education to alleviate credit market constraints, spending on the environment to reduce pollution, spending on natural resources to establish property rights, spending on research and development to internalize positive spillover effects and spending on the optimal provision of public goods are examples of this type of expenditure. On the other hand, “expenditures on private goods” refer to government expenditures that do not alleviate market failure and may even increase market inefficiency. Agricultural subsidies and fossil fuel production incentives are examples of such expenditures.

Expenditures on public goods can affect the choice to clear forest land through the cost of land clearing and agricultural productivity. Expenditures on public goods allow for the creation of institutions that enforce laws that protect property rights (Polinsky and Shavell 2000; Williamson 2000) and are essential to sustainable use of natural resource stocks. Furthermore, the provision of public goods complements other inputs in different sectors (López et al. 2011) thereby augmenting agricultural productivity. Expenditures on private goods are usually targeted towards specific sectors. Agricultural subsidies such as irrigation subsidies and input subsidies in South America (Bulte et al. 2007) are classic examples of such types of spending and also tend to increase agricultural productivity.

Early empirical work relied on reduced form estimation using cross-country forest cover data (Southgate 1991; Cropper and Griffiths 1994; Shafik 1994; Antle and Heidebrink 1995) to allow for a broad measure of the effect of underlying factors on deforestation. However, the mechanisms by which those factors affect forest cover are not elucidated which hinder accurate policy prescriptions to reduce deforestation. Also, FAO data on forest cover that are used for these types of analysis have been deemed unsatisfactory for econometric estimation (Angelsen and Kaimowitz 1999).

More recent empirical estimates from micro studies rely on data from local surveys, remote sensing and satellite images (Cropper, Puri, and Griffiths 2001; Chomitz and Thomas 2003; López 1997, 2000). Using detailed forest data allows for accurate measures of the direct factors affecting deforestation but given the local nature of the forest cover data and limited observations over time, measuring the effect of the underlying factors is difficult.

López and Galinato (2005) bridged the link between underlying factors with estimates from micro studies by combining elasticities from microstudies with elasticities from regressions explaining the determinants of direct factors of deforestation. Galinato and Galinato (2013) extended the analysis by including more countries and focusing on the short-run and long-run effects of political stability and corruption control on deforestation. Galinato and Galinato (2012) simulated the effects of the two governance variables on deforestation-induced carbon emissions.

We add to the literature by focusing on the effect of the level and composition of public spending as our main underlying factors affecting the direct factor of deforestation, which is forest land clearing for production of agricultural crops. Using these estimates we simulate the effect of changes in fiscal policy on carbon release from deforestation. This is the first study we are aware of that distinguishes the long-run and short-run effects of government spending on forest cover and deforestation-induced carbon emissions.

Our model illustrates the mechanisms by which a change in the size and composition of fiscal spending affects deforestation-induced carbon emissions through changes in land use from forest cover to agricultural land. We show that when the marginal cost of land clearing brought about by an increase in expenditures on public goods is lower than the value of marginal product from such expenditure, there is more forest land cleared in the short run leading to a lower steady-state forest cover and more carbon dioxide emitted. The effects are more pronounced when total government spending is considered since the value of marginal product of agriculture is higher with the contribution of expenditures on private goods. Our empirical model finds support for our theoretical results. We show that expenditures on public goods alone have a positive but insignificant effect on forest land clearing for agricultural production due to the countervailing effects of the marginal cost of land clearing and the value of marginal product of land. However, total government spending significantly increases forest land clearing and related deforestation-induced CO_2 emissions in the short run. Interestingly, government spending does not have any lingering effects in the long run.

Our results highlight two important contributions. First, we show the difference in the mechanisms by which government spending affects production-based pollution versus pollution from land use change. López, et al. (2011) showed in their static general equilibrium model that a change in the composition of government spending towards expenditures on public goods significantly reduces production-based pollution but increasing total spending alone has no significant effect. In contrast, we find the opposite result where a change in government spending composition has no effect on deforestation-induced CO_2 emissions because of a simultaneous increase in the marginal cost and marginal benefits of land clearing. We also show that the level of government spending significantly increases pollution from forest land clearing. Second, we find an unintended consequence from increased fiscal spending and broadening safety nets: more pressure may be placed on clearing forest land to produce crops leading to more carbon dioxide emissions in the short run but the pressure is dissipated in the long run.

In this article, we present the theoretical framework that serves as the foundation for the empirical model. Next, we describe the data and present our empirical estimates and simulations. Finally, we conclude the study.

II. THEORETICAL MODEL

We consider a partial equilibrium where an agricultural sector exists with a dynamic natural resource stock. We focus on agricultural production in developing economies with tropical areas such as Brazil. Here, farmers clear forest land in order to cultivate cash crops that may be exported to other countries and farmers may establish ownership through use of the land. Given the open access nature of the forest stock, we assume that farmers do not internalize their effect on the forest cover and carbon release.[2]

Assumptions

The government affects the agricultural sector based on their allocation of total public expenditure, G. They may allocate government spending to expenditures on public goods that alleviates market failure, g, such as those that enforce property rights regimes, provide public road systems and invest in research and development that produce new agricultural technology. On the other hand, the government may also decide to increase expenditures on private goods that subsidize firm production without alleviating market failure, x, such as irrigation or fertilizer subsidies.[3] Here, we assume that the government's budget constraint holds where $G=g+x$.

Aggregate production in the agricultural sector is written as,

(1) $$Y = Y(K, L, F, A; g, x)$$

where Y is output, L is labor, K is capital, A is amount of forest land cleared and F is forest cover.[4] We assume that the entire amount of land cleared A is also immediately converted into agricultural land such that A is also the amount of agricultural land planted. The forest cover itself can affect crop yield because soil quality is affected by an adequate stock of forest biomass which prevents flooding and soil erosion. We assume that the production function is increasing and concave in the four inputs of production. Following López et al. 2011, we assume that g complements K and L such that $Y_{Kg} > 0$ and $Y_{Lg} > 0$, but x complements L and substitutes for K such that $Y_{Kx} < 0$ and $Y_{Lx} > 0$.[5] Finally, both variable inputs are complements, $Y_{KL} > 0$ and forest biomass complements all inputs, i.e. $Y_{AF} > 0$, $Y_{AK} > 0$ and $Y_{AL} > 0$.

For a given level of forest land cleared for agricultural production, the stock of forest cover declines by a proportion β. Following López (1994), we assume that the natural growth rate of the forest equals α leading to a change in stock of forest cover,

(2) $$F_{t+1} - F_t = \alpha F_t - \beta A_t.$$

Due to the change in forest cover, there is also a corresponding change in the amount of carbon released into the atmosphere. There is a constant rate of carbon emitted from other sources, θ, such that the carbon dynamics are,

(3) $$C_{t+1} - C_t = \theta C_t - \delta F_t + \gamma A_t,$$

where δ is the rate at which forest cover emits (sequesters) carbon dioxide when F is increasing (decreasing) and γ is the contribution of agricultural production to carbon dioxide emissions. Greenhouse gas emissions unambiguously occurs from deforestation as shown by $\delta > 0$ and F is declining. There may be net emissions throughout the lifecycle of agricultural production such that $\gamma < 0$;[6] however, it may also lead to a net positive carbon sequestration from plant growth $\gamma > 0$.

We assume that farmers take input and output prices as given because they can purchase capital and labor in competitive markets and their final good can be sold in competitive markets as well. The farmer maximizes profit by optimally selecting variable inputs, K and L, and a quasi-fixed input A. Input choices occur in two stages during each time period. First, the farmer decides how much forest land to clear given the government's choice of public expenditure allocation. Next, the farmer purchases capital and labor given the amount of forest land cleared. Since the farmer does not internalize the dynamics of carbon and forest stock, we can analyze the behavior of agents one period at a time.

Solution through Backward Induction

We start with Stage 2 where labor and capital are optimally purchased by the farmer given public expenditure levels and the amount of forest land cleared,

(4) $$\pi(F, A; g, x, w, r, p) \equiv \max_{K,L}\{pY(K, L, F, A; g, x) - wL - rK\}$$

where p is the price of the agricultural output, w is an exogenous wage rate and r is an exogenous price of capital. Taking the first order conditions with respect to each variable input, we find that the value of marginal product of each input is equal to the input price,

(5) $pY_L(K, L, F, A; g, x) - w = 0$;

(6) $pY_K(K, L, F, A; g, x) - r = 0$.

It is easy to show that when farmers commit to more land clearing, there is an increase in capital and labor in the agricultural sector, $\frac{\partial K}{\partial A} > 0$ and $\frac{\partial L}{\partial A} > 0$ as long as the variable inputs are complements with A.

Government spending has a direct effect on capital and labor choice but there is also an indirect effect through the amount of forest land cleared for agricultural production. The direct effect of g is to increase both variable inputs $\frac{\partial K}{\partial g} > 0$ and $\frac{\partial L}{\partial g} > 0$ since g complements both variable inputs. In contrast, given the assumption that x and K are substitutes, a rise in x directly reduces the amount of capital purchased but a countervailing effect occurs where K increases because we assume capital and labor are complements. This leads to an ambiguous effect of x on both variable inputs.

Our focus is to determine the indirect effect of government spending through forest land clearing for agricultural production in Stage 1. In Stage 1, the optimum level of forest land cleared for agricultural production is chosen by maximizing the following,

(7) $\max_A \quad \pi(F, A; g, x, w, r, p) - c(g)A,$

where $c(g)$ is the cost of forest land clearing and we assume that $c_g > 0$. The resulting first order condition, V, shows that,

(8) $V \equiv \pi_A(F, A; g, x, w, r, p) - c(g) = 0.$

Here, A is chosen such that the value of marginal product of A is equal to the marginal cost of land clearing. The decision of farmers to clear forest land for agricultural production is fully governed by (8) since they do not internalize the dynamics of (2) and (3) such that,

(9) $A^* = H(F, g, x, p, r, w).$

Figure 1 illustrates the trajectory and steady-state levels of forest cover and forest land clearing under open access. The forest stock isocline, $F_{t+1} - F_t = 0$, is an upward sloping line starting at the origin with a slope α/β. At any point above $F_{t+1} - F_t = 0$, forest stock decreases while below it forest stock increases. Also, $V = 0$ from (8) governs the amount of forest land to clear for agricultural production in every time period. It is positively sloped given our assumption on production because, $\frac{dA}{dF} = -\frac{V_F}{V_A} = -\frac{pY_{AF}}{pY_{AA}^A} > 0$.

At F(0), the farmer clears at A(0) of forest land to produce crops. As more forest land is cleared for agricultural production, the forest cover declines which reduces the value of marginal product in the agricultural sector. This leads to a reduction in variable inputs resulting in less forest land clearing. Since we are above $F_{t+1} - F_t = 0$, there is a movement along $V = 0$ down and to the left until the steady-state forest land clearing for agricultural production at A^{ss} and forest stock at F^{ss} are reached.

The Effect of Government Spending on Forest Cover and Carbon Dioxide Emissions

Government expenditures affect the steady-state level of cleared forest land for agricultural production as well as the trajectory path towards the steady state through their direct effects on production and the marginal cost of land clearing. The effect of *g* is such that $V_g = \pi_{Ag}(F, A; g, x, w, r, p) - c_g(g)$. There are two countervailing effects of public goods expenditure on marginal profit in the agricultural sector. Any increase in *g* increases the marginal cost of forest land clearing as more protection for the environment is in place. However, investment in agricultural research and development and public infrastructure such as roads increases the value of marginal product of cleared land in agriculture. When the latter effect outweighs the former effect, the line *V=0* shifts up, otherwise it will shift down.

When total government spending, *G*, rises, there is an additional contribution to the value of marginal product of agriculture through an increase in *x*. Here, the line *V=0* is more likely to shift up since $V_G = V_x + V_g = \pi_{Ag} + \pi_{Ax} - c_g$. Thus, it is more likely that we see a short-run increase in forest land clearing for agricultural production but a lower steady-state level of forest land cleared in the long run. Fan and Zhang (2008) provide empirical support showing that there is a significant rise in marginal productivity in agriculture from Uganda as government spending targeted in extension and research and development increases.

At the initial steady-state forest cover, F^{ss}, forest land is cleared for agricultural production at A^{ss} as illustrated in Figure 1. A rise in G increases the value of marginal product of agriculture and marginal cost of land clearing for any given level of forest stock. If the former effect outweighs the latter effect, the $V=0$ line will shift up from $V = 0$ to $V' = 0$. In the short run, this will cause an instantaneous increase in forest land cleared for agricultural production leading to a reduction in the forest cover. The trajectory follows $V' = 0$ down and to the left because as F is reduced, the value of marginal product declines leading to less forest land cleared. In the long run, a lower steady-state stock is reached at F^{ss1} along with a lower steady-state cleared forest land at A^{ss1} compared to the initial steady state.[7]

The slopes of $V = 0$ and $F_{t+1} - F_t = 0$ play a crucial role in determining the short-run and long-run effects of government spending on the amount of land converted towards agricultural production. A combination of a steep $V = 0$ line and flat $F_{t+1} - F_t = 0$ line indicates a relatively large effect of government spending on short-run agricultural land clearing, i.e., a large increase from A^{ss} to A^{G}, but a small change in the long-run agricultural land clearing, i.e., small difference between A^{ss} to A^{ss1}. However, as $F_{t+1} - F_t = 0$ becomes relatively steeper, the long-run effects on the steady state become larger. The slope of the $F_{t+1} - F_t = 0$ depends on the regeneration coefficient of the forest, α, and the negative effect of agricultural conversion, β, where a lower regeneration coefficient implies a flatter $F_{t+1} - F_t = 0$ line.

Figure 2 illustrates the impact of G on carbon stock levels where agricultural production leads to a net decline in carbon dioxide emissions, i.e. $\gamma < 0$. In (C,A) space, equation (8) is drawn as a horizontal line because $\frac{dA}{dC} = -\frac{V_C}{V_A} = 0$ since $V_C = 0$. The carbon stock isocline, $C_{t+1} - C_t = 0$, is upward sloping with a slope of $\frac{dA}{dC} = \frac{\theta}{\delta\frac{dF}{dA} - \gamma}$ since $\frac{dF}{dA} > 0$ and $\gamma < 0$.[8] To the right of the isocline, carbon dioxide emissions increase and to the left carbon dioxide emissions are reduced. Assuming an initial steady-state level of agricultural production at A^{ss}, it is not clear if carbon dioxide emissions are increasing, decreasing, or not changing. Solving for the steady-state forest stock as a function of steady-state agricultural production, we find that there is no change in carbon stock when $C = \left(\frac{\delta\beta - \gamma\alpha}{\alpha\theta}\right) A^{ss}$. A higher carbon stock than this level will increase carbon dioxide emissions while a lower level carbon stock will decrease it.

An increase in G will shift the profit line to $V'(A') = 0$, implying more forest land is cleared for agricultural production, when the value of marginal product is higher than the marginal cost of land clearing.[9] This results in a larger segment by which carbon dioxide emissions can decline in the short run. Intuitively, this is because more agricultural production has the potential to yield a net increase in carbon sequestration. However, as the forest cover is depleted, agricultural production steadily decreases until the new steady state at $V^{ss1}(A^{ss1}) = 0$. Here, the segment representing a potential for decline in carbon dioxide emissions is smaller in the long run due to a lower forest cover and a lower steady-state level of agricultural production.

III. EMPIRICAL MODEL

We determine the effect of government spending on forest cover and deforestation-induced carbon emissions in three stages. First, we estimate the effect of government spending on forest land clearing for agricultural production and derive the corresponding elasticity. Next, to derive the total effect of government spending on forest cover change, we combine our elasticity estimates in stage 1 with estimates from micro studies relating the effect of forest land clearing on forest cover. Finally, we simulate the change in carbon dioxide emissions given a change in government spending from the elasticity of forest cover.

Deriving the Effect of Government Spending on Forest Land Clearing for Production of Agricultural Crops

We measure the effect of expenditures on public goods for forest land clearing by estimating an empirical model where (9) is substituted into (2). Successive substitutions of equation (2) yields,

(10) $F_t = \left(\frac{1}{1-\alpha}\right)^t F_0 - \beta \sum_{n=0}^{t} \left(\frac{1}{1-\alpha}\right)^{n+1} A_{t-n} = F(F_0, A_t, A_{t-1}, A_{t-2}, \ldots)$

where F_0 is the initial forest stock and A_{t-n} is lagged forest land cleared for agricultural production. Recall that we assume A is immediately converted into agricultural land, hence A_{t-n} is also the lagged agricultural land planted. Divide and multiply g and x by G, where $G \equiv g+x$ is total government spending, and then normalize G by consumption per capita, c. Using (10) into (9), along with the above simplifications and solving for A_t yields,

(11) $A^*{}_t = H(s, 1-s, \bar{G}, p, r, w, F_0, A_{t-1}, A_{t-2,\ldots})$,

where $s \equiv g/G$ is the share of expenditures of public goods in total government spending and $\bar{G} \equiv G/c$ is the share of government spending in total size of the economy.

From (11) we derive the following empirical relationship,

$$(12)\ \ln A_{it} = \alpha_1 \ln s_{it} + \alpha_2 \ln \bar{G}_{it} + \alpha_3 \ln p_{it} + \alpha_4 \ln r_{it} + \alpha_5 \ln w_{it} + \alpha_6 \ln F_{0i} + \sum_{n=1}^{X} \alpha_{6+n} \ln A_{it-n} + \varepsilon_i + \sigma_t + \mu_{it},$$

where subscripts i and t represent country and time, respectively and α_j (j=1,..,X) are fixed parameters. Thus, A_{it} and A_{it-n} are the amounts of forest land cleared for agricultural production in country i at year t and t-n, respectively; s_{it} is the share of public goods expenditure in country i at time t; $\bar{G}_{it}$ is government consumption expenditure over gross domestic product (GDP); p_{it} is an index of agricultural crop prices planted in cleared forest land in country i at year t; r_{it} is the price of investment in country i at year t; w_{it} is the wage in the agricultural sector in country i at year t; F_{0i} is the land area of the country which is a proxy for the initial forest cover; ε_i is a country effect which can be fixed or random; σ_t is a time effect common to all countries; and μ_{it} is a random disturbance with the usual desirable properties.

To determine if the share of expenditures on public goods and aggregate government spending increases forest land clearing in the short run, we determine if α_1 and α_2 are positive and significantly different from zero, respectively. The long-term effect of these variables are calculated using the formula $\frac{\alpha_1}{1-\sum_{n=1}^{X}\alpha_{6+n}}$ and $\frac{\alpha_2}{1-\sum_{n=1}^{X}\alpha_{6+n}}$ for the share of expenditures on public goods and aggregate government spending, respectively.

A few notes regarding the estimation of (12) are in order. First, estimation of a dynamic panel lagged model requires the use of generalized method of moments to obtain consistent estimates given a fixed sample size (Arellano and Bond 1991). Our theoretical model does not give guidance on the number of lagged dependent variables. We increase the number of lags until the lag effect becomes insignificant. Next international shocks, such as changes in the international interest rate, may have common effects across countries. We use time dummies to capture the effect of this variable. Also, there are many unobserved characteristics of countries which we capture using fixed or random effects. Next, endogeneity may affect the crop price index because they may be affected by forest land cleared. We test formally for endogeneity of the crop price index using a Hausman test with annual precipitation[10] as an instrument since rainfall could affect the value of production and therefore its price, but rainfall is unlikely correlated with forest degradation directly. We fail to reject the null hypothesis of exogeneity. Furthermore, since the effects of fiscal spending are likely to occur in subsequent periods, we use lagged size of government spending and lagged share of public goods expenditure instead of current levels. Finally, we could not find a consistent measure of wages that overlapped with the time frame of our dataset so we used GDP per capita from the agricultural sector as a proxy. We lagged this variable to minimize any potential for reverse causality.

The Effect of Government Spending on Forest Cover and Carbon Dioxide Emissions

The total effect of government spending on forest cover is derived by multiplying the elasticity from (12) with the elasticity relating forest land clearing to forest cover in (10). The short-run and long-run effects of the share of expenditures on public goods and aggregate government spending on forest cover are,

(13) $\epsilon_k^{Fs} = \epsilon_A^{Fs}\alpha_k$ and $\epsilon_k^{Fl} = \epsilon_A^{Fl}\frac{\alpha_k}{1-\sum_{n=1}^{X}\alpha_{6+n}}$ for k =1,2,

where k = 1 represents the effect of the share of public goods expenditures and, k = 2 represents the aggregate government spending. Furthermore, $\epsilon_A^{Fs} \equiv -\frac{\beta}{1-\alpha}\frac{A}{F}$ and $\epsilon_A^{Fl} \equiv \frac{\beta}{\alpha}\frac{A}{F}$ are the short-run elasticity and long-run elasticity, respectively, of forest land clearing for agricultural production on forest cover.

Through successive substitutions of (3), we find that the current carbon sequestration level is equal to,

(14) $C_t = \left(\frac{1}{1-\theta}\right)^t C_0 - \delta \sum_{n=0}^{t} \left(\frac{1}{1-\alpha}\right)^{n+1} F_{t-n} + \gamma \sum_{n=0}^{t} \left(\frac{1}{1-\alpha}\right)^{n+1} A_{t-n}$,

where C_0 is the initial carbon stock and F_{t-n} are lagged forest levels. Thus, the short-run and long-run elasticities illustrating the effect of a change in the fiscal policies on carbon emissions are equal to,

(15) $\epsilon_k^{Cs} = \epsilon_F^C \epsilon_k^{Fs} + \epsilon_A^C \alpha_k$ and $\epsilon_k^{Cl} = \epsilon_F^C \epsilon_k^{Fl} + \epsilon_A^C \frac{\alpha_k}{1-\sum_{n=1}^{X} \alpha_{5+n}}$ k =1,2

where ϵ_k^{Cj} for $j = s, l$ are the short-run and long-run elasticities of carbon sequestration with respect to the government spending variables $k = 1,2$; $\epsilon_F^C \equiv \frac{\delta}{1-\alpha}\frac{F}{C}$ is the elasticity of carbon with respect to forest cover; and, $\epsilon_A^C \equiv \frac{\gamma}{1-\alpha}\frac{A}{C}$ is the elasticity of carbon with respect to agricultural production.

IV. DATA

We collect data to estimate the determinants of forest land clearing for agricultural production in (12) and gather parameter estimates to derive the effects of government spending on forest cover and carbon dioxide emissions in (13) and (15).

Determinants of Forest Land Clearing for Agricultural Production

We compile an unbalanced cross-country panel data set. Countries are initially selected using a criteria developed by López et al. (2002).[11] We eliminate countries where forest land clearing is not primarily driven by agricultural land use. This approach narrows our sample of countries to Latin America where there is a prevalence of slash and burn agriculture (Houghton et al. 1991), and Asia, especially in Southeast Asian countries, due to shifting cultivation in mountainous regions (Rerkasem et al. 2009).[12]

We present the descriptive statistics used in deriving the determinants of forest land clearing in Table 1. There are two key variables in our study. First, we calculate our own measure of forest land cleared for agricultural production. To do so, we identify the primary crops growing near forest land and classify it as a crop encroaching on forest land only if there is a study or report identifying it as such. Based on this literature search, we derive the total amount of agricultural land planted for each crop that we identify as encroaching on forest land from the FAO and add up the total land area planted for all these crops. We use this measure to represent the amount of forest land cleared to produce agricultural crops. Unlike other studies that use the total amount of land harvested, we avoid overestimating the effect of this variable on forest cover by focusing only on crops that are planted in previously forested areas.

The second key variable is a measure of government spending. We use two measures. First, government consumption expenditure data over GDP is used to proxy aggregate spending and is obtained from the Government Financial Statistics database compiled by the International Monetary Fund (IMF). We use data from the Asian Development Bank to supplement the IMF data for some Asian countries. We create our own measure of the composition of expenditures on public goods in total government expenditures by adding all the subcategories for such expenditure and dividing it by the aggregate government spending variable. Expenditures on public goods include spending in education, health, social welfare, transport, communications, public order and safety, research and development, environment, recreation and culture, and social housing. Appendix A lists the twelve countries in our sample along with crops that we identify as encroaching on forest land based on our survey of studies that also have available data on spending and forest land clearing for agricultural production.[13]

Other variables in our regression are the crop price index, price of capital investment, agricultural GDP per capita and land area. We derive the latter variable from the World Bank database while the price of capital is from the Penn World Tables. We calculate the crop price index from the set of selected crops using the Laspeyres index formula. Agricultural GDP per capita is calculated using data from the World Bank. Appendix B summarizes the sources for our data.

Forest Cover and Carbon Sequestration Elasticities

Recall that using FAO forest data for econometric estimation has been deemed unsatisfactory and that an alternative is to rely on estimates from micro studies. We summarize the parameters used in our study in Table 2. To make our estimates comparable with the parameter estimates of micro studies derived from different countries, we adjust the elasticity of forest land clearing for agricultural production on forest cover. First, we use the implied marginal effects from the studies we selected and then calculate the elasticity of forest land clearing on forest cover using the implied marginal effects along with the average forest cover and average area of forest land cleared in our sample.

The short-run and long-run effects of forest land clearing for agricultural production on forest cover came from two studies. The short-run effect of crop area on forest cover was taken from López (2000) who estimated the effect of cultivation on forest clearing in rural villages in Western Ivory Coast. He found that a one hectare increase in cultivated area resulted in 4.4 hectare decrease in forest cover because the conversion of forest cover to agricultural land requires additional clearing for human settlement and infrastructure supporting agricultural production.[14] The long-run effect is taken from Maertens et al. (2006). They found that one hectare of shifting cultivation in Indonesia from 1980-2001 led to 0.88 hectares of reduced forest cover because abandoning the area could have led to re-growth of natural forest vegetation.

There are two mechanisms by which government spending affects carbon dioxide emissions. The first is through the change in forest cover, which is approximated by change in forest biomass. We use the conversion coefficient formula from Naughton-Treves (2004) which relates the amount of carbon dioxide emissions, ψ, to the aboveground live forest biomass. Here, $\psi = \lambda \cdot \theta \cdot \rho$, where λ is aboveground live biomass of forest in megagrams per hectare (Mg/ha); θ is the CO_2 fraction of dry biomass; and ρ is the burning efficiency of forest clearance, which refers to the percentage of heat content in the wood that can be extracted and used. The parameters for primary and secondary forests differ as shown in Table 2.

The second mechanism where government spending affects carbon dioxide emissions is through agricultural production. Cropping systems significantly affect the level of carbon dioxide emitted or sequestered during the production process. Samarawickrema and Belcher (2005) simulate that under conventional tillage, there is about 2 tCO_2e/ha/year carbon sequestered and 0.9 tCO_2e/ha/year of emissions leading to a net intake of carbon equal to 1.1 tCO_2e/ha/year. In contrast, under no tillage there is 2.9

tCO_2e/ha/year carbon sequestered and 0.9 tCO_2e/ha/year of emissions leading to a net intake of carbon equal to 2 tCO_2e/ha/year.

V. EMPIRICAL RESULTS

To determine the total effect of government spending on deforestation-induced carbon dioxide emissions, we first present our regressions results deriving the determinants of forest land clearing for agricultural production and then combine the elasticities with parameter estimates from the literature.

Determinants of Forest Land Cleared for Agricultural Production

We present Ordinary Least Squares (OLS), Fixed Effects (FE), Random Effects (RE) and Generalized Method of Moments (GMM) that estimate equation (12) in Table 3. We calculate standard errors robust to autocorrelation and heteroskedasticity. We find that lagged forest land cleared for agricultural production is significant in all the GMM models and is significant only after one period. Here, a 1% increase in agricultural land expansion in the previous period increases current agricultural land expansion by a similar magnitude. Thus, omitting lagged agricultural land expansion in our model would bias our estimates such as those presented in OLS, FE and RE.

In the models that do include lagged forest land clearing, we find that the effects of our two fiscal policy variables are consistent with our theoretical model.[15] The share of expenditures on public goods has a positive effect on forest land clearing but insignificant in all GMM models. One potential explanation from our model is the two countervailing effects from expenditures on public goods where it can increase the value of marginal product of agricultural output but it can also raise the marginal cost of land clearing.

Based on our estimates, the two effects may offset each other leading to a statistically insignificant effect of the share of government expenditure on public goods.

In contrast, the share of aggregate government expenditure relative to GDP is consistently positive and significant. When government expenditure over GDP increases by 10%, we find that forest land clearing rises by approximately 2%. Again, our theoretical model provides some intuition as to why we obtain such an estimate. Increased government spending not only raises “expenditures on public goods” but it increases “expenditures on private goods” as well which together contribute to a further increase in the value of marginal product of agriculture. The net increase in value of marginal product from both types of spending may outweigh the rise in marginal cost of land clearing from “expenditures on public goods” alone leading to more variable inputs and an increase in forest land clearing in the short run.

Table 4 compares the short-run effects of fiscal spending from their long-run effects. We find that the long-run effect of the share of expenditures on public goods is still insignificant. Interestingly, the long-run effect of government expenditure relative to GDP becomes negative and insignificant. Our theoretical model provides a plausible explanation of this result. When the regeneration rate of the forest is relatively low, we obtain a relatively flat $F_{t+1} - F_t = 0$ line. Couple this with a steep $V = 0$ line and an increase in government spending leads to a sharp increase of forest land cleared for agricultural production as shown in our short-run elasticity of government spending. However, the new steady-state level of forest land cleared for agricultural production is lower than the original steady-state level but it may not be significantly lower, which leads to an insignificant effect of government spending in the long run.

Effect of Government Spending on Forest Cover and Deforestation–induced Carbon Emissions

Using Equation (13), we calculate the effect of government spending on forest cover by combining our estimates in the GMM with time dummies specification in Table 3 with those from the literature in Table 2. The composition of government expenditure continues to have no significant effect on forest cover in the short run and the long run as shown in Table 4. However, the share of government expenditure relative to GDP significantly reduces forest cover in the short run. Also, since the steady-state level of forest land cleared is lower but insignificant, the long-run effect of government expenditure over GDP reduces steady-state forest cover but the effect is also insignificant. Thus, there is no lingering effect of government expenditure on forest cover in the long run.

We determine the effect of changes in government spending for Brazil, the country with the largest forest area in our sample. The average share of government expenditure relative to GDP for Brazil is 26%. The country with the highest share of government expenditure in our sample is Nicaragua at 37%. If Brazil would steadily increase the share of government expenditure relative to GDP at the same level as Nicaragua, our estimates predict an immediate decline in forest cover by 0.5%.

We also derive the short-run and long-run effects of government spending size and composition on carbon dioxide emissions. Similar to our previous analysis, it is the aggregate government spending relative to GDP that matters and not the composition of government spending. We find that there is a short-run increase in carbon dioxide emissions but no significant effect in the long run. In the short run, when agricultural production increases, there is also a net decrease in carbon dioxide emissions which partially negates the carbon dioxide emissions when forest land is cleared leading to a lower elasticity value in the short run than the long run. It must be noted that the short-run carbon dioxide emissions should be treated as a lower bound estimate regarding the aggregate carbon dioxide emissions even if the long run is insignificant. This is because a medium run exists during the transition periods toward the new steady state which leads to more land clearing and related carbon dioxide emissions.

Our results are in contrast to those found by Lopez et al. (2011) when they investigated the effect of expenditure composition and expenditure levels on production pollutants from dirty manufacturing firms. They found that changing the composition of government spending towards expenditures on public goods significantly reduced pollutants such as sulfur dioxide, lead and biological oxygen demand while government consumption expenditure has no significant effect. In contrast, deforestation-induced carbon dioxide emissions are affected by aggregate government spending relative to GDP but not by the composition of government spending. This result is attributed to the differences in the mechanisms by which the size and composition of government spending affect the production pollutants versus deforestation-related pollution. In our case, countervailing effects of expenditures on public goods lead to an insignificant effect on forest land cleared for agricultural production. However, when aggregate government spending rises, implying an increase in both public and private goods expenditures, the value of marginal product of agriculture increases resulting in more demand for agricultural land, which reduces forest cover and increases carbon dioxide emissions.

Our results also contrast the findings of Halkos and Paizanos (2013) who analyzed the effect of aggregate government spending on CO_2 emissions from energy and transportation. They show that government spending significantly reduces income per capita leading to lower CO_2 emissions. In contrast, we show that the link of government spending on deforestation-induced CO_2 emissions is positive because of a change in land use (i.e., agricultural land expansion) that reduces forest cover.

VI. CONCLUSION

This article presents theoretical and empirical models linking the mechanisms by which the size and composition of fiscal policies affect forest cover and deforestation-induced carbon dioxide emissions. We have shown that the composition of government expenditure does not have any effect on forest land clearing for agricultural production which implies that it also does not have any effect on deforestation-induced CO_2 emissions. Our theoretical model provides a plausible explanation to this result. Countervailing effects of expenditures on public goods may occur such that an increase in the marginal cost of land clearing, which reduces forest land clearing, is offset by a rise in the value of marginal product of agriculture, which has an opposite effect on forest land clearing.

In contrast, aggregate government spending induces forest land clearing for agricultural production thereby increasing deforestation-induced CO_2 emissions in the short run. However, there is no lingering effect in the long run since the decline in steady-state forest cover and steady-state agricultural production is insignificant. Again, our theoretical model provides one plausible explanation. Aggregate government spending increases the value of marginal product and may outweigh the higher marginal cost of land clearing leading to more forest cleared for agricultural production in the short run. Also, if the forest regeneration rate is low, the steady-state forest cover will not be significantly affected leading to no lingering long-run effect.

The short-run CO_2 emissions are a lower bound on aggregate emissions from government spending. Since the short run results in a movement away from the steady state, the transition periods toward the new steady state leads to more land clearing and more CO_2 emissions.

The results have important policy implications especially during times of recession when developing countries expand social safety nets and increase the share of government spending in total GDP. Even though aggregate government spending does not have any significant effect on production-based pollutants (Lopez et al. 2011), we show that it has significant negative consequences in terms of land use change and increased deforestation-induced carbon dioxide emissions in the short run. This does not mean that we are advocating against policies that increase the size of government spending during times of recessions. In fact, based on our theoretical framework, one way to mitigate an increase in deforestation-induced carbon dioxide emissions due to an increase in the size of government spending is to have more targeted spending that protect natural resource stocks by enforcing property rights and dissuading forest land clearing especially during times of recession.

Appendix A. List of Countries and Agricultural Crops Encroaching on Forest Land

Country	Crop/s
Argentina	Cotton, Maize, Soybeans
Brazil	Banana, coffee, maize, rice, soybeans, cassava/tapioca, beans (including cowpeas and other types)
China	Soybeans
Costa Rica	Banana, mango
Ecuador	Cacao, coffee, manioc/cassava, naranjilla, tea, palm oil, rice, maize
India	Soybeans
Mexico	Maize, commercial chili
Nicaragua	Palm fruit
Panama	Coffee
Philippines	Cassava, corn, rice, sweet potato
Thailand	Cassava
Venezuela, RB	Banana, coffee, maize, tobacco, cassava, sugar cane, citrus fruit

Note: Agricultural crops encroaching on forest land refer to crops identified in studies that are planted along shifting agricultural frontiers converted from forest land. Given space limitations, we do not include here the citations from each individual study that helped us identify these crops. The citations are available from the authors on request.

Appendix B. Definition and Sources of Variables Used in the Study

Variable name	*Definition*	*Source/s*
Forest land cleared for agricultural production (ha)	Total area harvested of crops encroaching on forest land in hectares. Crops that encroach on forest land are identified through a literature survey. The total area harvested for all identified crops are added up. This measure was used to represent the area of forest land cleared to produce agricultural crops.	Author's calculation using data from FAOSTAT – Production[a]
Government consumption expenditure over GDP	General government final consumption expenditure (formerly general government consumption) includes all government current expenditures for purchases of goods and services (including compensation of employees). It also includes most expenditures on national defense and security, but excludes government military expenditures that are part of government capital formation.	Government Financial Statistics (IMF), Asian Development Bank, Country data
Share of public goods expenditure	Public goods in total government expenditures include: education, health, social security, transport, communication, public order and safety, housing and community amenities, environmental protection, religion and culture.	Author's calculation using date from Government Financial Statistics (IMF), Asian Development Bank, Country data
Crop price index	Calculation is based on the Laspeyres index formula: $P = \frac{\sum (p_c t_n \times q_c t_0)}{\sum (p_c t_0 \times q_c t_0)}$ where P is the change in price level, p_c,t represents the prevailing price of crop c in period t, q_c,t is the quantity of crop c sold in period t, t_0 is the base period (year 2000), and t_n is the period for which the index is computed.	Author's calculation using data from FAOSTAT – Production (Crops) database and FAOSTAT - Production (PriceSTAT) database.[a]
Price level of investment	Price level of investment is calculated as the Purchasing Power Parity over Investment divided by the exchange rate times 100.	Penn World Table[b]
Wage		
Land area (ha)	Land area is a country's total area, excluding area under inland water bodies, national claims to continental shelf, and exclusive economic zones. In most cases the definition of inland water bodies includes major rivers and lakes.	World Bank Data Catalog

Note: [a] Food and Agriculture Organization of the United Nations (FAO). 2009. FAOSTAT – Production (Crops) and Prices (PriceSTAT) databases. Available at: http://faostat.fao.org/.
[b]Alan Heston, Robert Summers and Bettina Aten. 2012. Penn World Table Version 7.1, Center for International Comparisons of Production, Income and Prices at the University of Pennsylvania. Available at: https://pwt.sas.upenn.edu/php_site/pwt_index.php.
[c] The World Bank. 2013. Data Catalog. Available at: http://data.worldbank.org/.

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Tables

TABLE 1
Summary Statistics of Variables

Variable	Mean	Std. Dev.	Min	Max
Forest land cleared for agricultural production (ha)	2,810,483	5,948,092	10	46,900,000
Government consumption expenditure over GDP	0.19	0.07	0.11	0.55
Share of government expenditure in public goods	0.54	0.16	0.21	0.83
Crop price index	46.56	494.83	0.00	9,687.14
Price level of investment	526.30	4,261.64	3.89	54,298.54
Agricultural GDP per capita	911.04	751.37	33.85	4672.66
Land area (ha)	71,800,000	186,000,000	2,800	933,000,000

TABLE 2
Parameters Used in the Study

	Forest land[a]	Carbon dioxide emissions	
		Forest land[b]	Agricultural land[c]
Marginal effect of agricultural land clearing			
Short run	4.4 ha		
Long run	0.88 ha		
Carbon conversion coefficients			
Primary forest			
Aboveground biomass (λ)		407 Mg/ha	
CO_2 fraction of dry biomass (θ)		0.5	
Burning efficiency of forest clearance (ρ)		0.4	
Secondary forest			
Aboveground biomass (λ)		36.8 Mg/ha	
CO_2 fraction of dry biomass (θ)		0.5	
Burning efficiency of forest clearance (ρ)		0.6	
Net greenhouse gas emissions (tCO2e/ha/year)			
Conventional tillage			-1.1
No till			-2.0

Note: [a] Short-run estimate are taken from Lopez (2000) and the long-run estimate is from Maertens et al. (2006).

[b] We derive the burning efficiency estimates from Crutzen and Andreae (1990) and all other parameters are from Naughton-Treves (2004). To obtain the biomass from secondary forest, we multiply the average accumulation of aboveground biomass by the fallow period which Naughton-Treves (2004) assume to be 11.5 Mg C/(ha year) and 3.2 years, respectively.

[c] We use estimates from Table 6 of Samarawickrema and Belcher (2005).

TABLE 3
The Determinants of the *log* of Forest Land Cleared for Agricultural Production in South American and Asian Countries, 1986-1999

				Generalized Method of Moments[a]		Generalized Method of Moments[b]	
Variables	OLS[a]	Fixed Effects[a]	Random Effects[a]	1^{st} lag of dep. var.	1^{st} and 2^{nd} lag of dep. var.	1^{st} lag of dep. var.	1^{st} and 2^{nd} lag of dep. var.
Lag of log forest land cleared for agricultural production				1.012***	0.990***	1.012***	0.964***
				(0.028)	(0.104)	(0.028)	(0.118)
2^{nd} lag of log forest land cleared for agricultural production					0.023		0.048
					(0.117)		(0.121)
Lag of log government consumption expenditure over GDP	-2.005 ***	0.752	-2.005***	0.176***	0.180***	0.167***	0.173***
	(0.397)	(0.546)	(0.659)	(0.065)	(0.072)	(0.060)	(0.062)
Lag of log share of government expenditure in public goods	-2.358 ***	-0.017	-2.358***	0.028	0.030	0.028	0.029
	(0.315)	(0.168)	(0.877)	(0.057)	(0.062)	(0.063)	(0.064)
Log of crop price index	0.100 ***	-0.026 **	0.100**	-0.010	-0.010	-0.007	-0.007
	(0.031)	(0.012)	(0.060)	(0.007)	(0.007)	(0.006)	(0.005)
Log of price level of investment	-0.382	-0.398	-0.382	0.115**	0.117**	0.114**	0.118**
	(0.272)	(0.348)	(0.598)	(0.056)	(0.058)	(0.053)	(0.054)
Lag of log of agricultural GDP Per capita	0.255 ***	0.297	0.255	-0.012	-0.012	-0.014	-0.014
	(0.124)	(0.296)	(0.277)	(0.013)	(0.014)	(0.009)	(0.010)
Log of land area	1.185 ***		1.185***	-0.022	-0.022	-0.022	-0.021
	(0.057)		(0.109)	(0.033)	(0.035)	(0.031)	(0.032)
Constant	-11.956 ***	14.978 ***	-11.956***	0.261	0.263	0.176	0.173
	(1.639)	(2.535)	(2.817)	(0.429)	(0.435)	(0.399)	(0.406)
No. of observations	118	118	118	118	118	118	118
No. of groups		12	12	12	12	12	12
No. of instruments				34	34	34	34
Hausman test for overidentification			0.000***				
(prob Chi-square)				1.00	1.00	1.00	1.00
Arellano-Bond test for AR(1)				-2.24***	-2.65 ***	-2.40***	-2.56 ***

Arellano-Bond test for AR(2)	0.04	-0.05	0.12	-0.03

Note: *** 5%, **10%, *15%. System General Method of Moments is used to estimate the dynamic panel models.

[a] With annual time dummies, [b]Without annual time dummies.

Standard errors are in parentheses. Standard errors from the Fixed Effects and Random Effects are calculated using clustered Huber-White standard errors which are robust heteroskedastic-consistent standard error estimates. Standard errors from the Generalized Method of Moments are consistent with panel-specific autocorrelation and heteroskedasticity in one-step estimation.

TABLE 4
Elasticities of Forest Land Cleared for Agricultural Production, Forest Cover and Deforestation-induced Carbon Dioxide Emissions from Government Expenditure

	Forest Land Cleared for Agricultural Production	Forest Cover	Carbon Dioxide Emissions (Sequestration)		
			Agricultural Production	Forest Cover	Total
Short-run Elasticity					
Share of government expenditure relative to GDP	0.176***	-0.047***	-0.041***	0.276***	0.235***
	(0.065)	(0.018)	(0.015)	(0.104)	(0.089)
Share of expenditures on public goods	0.028	-0.007	-0.006	0.043	0.037
	(0.057)	(0.015)	(0.013)	(0.090)	(0.076)
Long-run Elasticity					
Share of government expenditure relative to GDP	-14.979	-0.800	3.457	4.696	8.152
	(33.964)	(1.819)	(7.838)	(10.675)	(18.501)
Share of expenditures on public goods	-2.357	-0.126	0.544	0.739	1.283
	(2.778)	(0.150)	(0.641)	(0.879)	(1.517)

Note: *** 5%, ** 10%, *15% levels of significance.

We use estimates from the GMM model with annual time dummies for our calculation. Asymptotically, the variance of a nonlinear univariate function, *g(A)*, is equal to $V(g(A)) = \left(\partial g / \partial A\right)^T V(A) \left(\partial g / \partial A\right)$ where $\partial g/\partial A$ is a vector whose i^{th} element is the partial derivative of g with respect to the i^{th} element A, and $V(A)$ is the variance-covariance matrix of the parameters in the vector A.

Figures

FIGURE 1
The effect of total government expenditures on forest cover

FIGURE 2
The effect of total government expenditures on carbon stock

Grouped Footnotes

[1] Road building and logging are two other important direct factors of deforestation. Recent estimates by Galinato and Galinato (2012, 2013) show that the effect of underlying factors through roads are significantly smaller in magnitude than through forest land clearing for agricultural production. Also, since initial logging is often followed by agricultural production in developing countries (López and Galinato 2005), it is difficult to empirically separate the two direct factors on deforestation. Thus, we opt to focus our analysis on only one direct factor: agricultural production. Note that we only focus on crop production and not livestock production because the mechanisms by which public spending affects deforestation may differ between the two production technologies.
[2] In Amazonian Ecuador for example, the Ecuadorian government passed a law which stated that claimants could establish ownership through use. Thus, the forest resource is considered open access until it is cleared and de facto ownership occurs. A significant number of peasants migrated to the Amazon. This migration resulted in settlement and deforestation during the late 1960s (Rudel 1995).
[3] There may be other types of spending that affect productivity in the agricultural or manufacturing sector directly, such as those that we listed above, or indirectly that influence consumer welfare such as subsidies to the rural poor to alleviate poverty.
[4] To reduce notation clutter, we suppress the time index *t*.
[5] Subscripts on functions denote derivatives, $\frac{dF}{dx} = F_x$ and $\frac{d^2F}{dx^2} = F_{xx}$.
[6] Globally, greenhouse gas emissions from forest land clearing account for 17% of global greenhouse gas emissions while agriculture accounts for 14% (IPCC 2007).
[7] If the marginal cost of land clearing has a greater effect than the rise in the value of marginal product of agriculture, the iso-profit line shifts down and the opposite effects occur.
[8] Note that when $\gamma>0$, $C_{t+1} - C_t = 0$ is still upward sloping for higher levels of carbon but there may be a downward sloping region at low levels of carbon.
[9] If the marginal effect of *G* on the value of marginal productivity of agriculture is less than the marginal cost of land clearing, then the iso-profit line shifts down instead and the opposite results hold.
[10] Precipitation data was taken from the Tyndall Centre for Climate Change Research available at: http://www.cru.uea.ac.uk/~timm/cty/obs/TYN_CY_1_1.html.
[11] All countries are plotted in a scatter plot to illustrate their absolute forest cover measure and proportion of forest land area to total land area. A hyperplane divides the countries into two sets: those with high absolute and high relative forest cover versus those that have low absolute and relative forest cover. We initially select those countries that are in the former set.
[12] We exclude countries from Africa and developed countries because the main driver of deforestation in the former was the collection and consumption of fuelwood as a source of energy (Cline-Cole, Main, and Nichol 1990) and urban development in the latter (EEA 2006).
[13] The Arellano Bond estimator is intended for the case where there are more groups than years. This assumption is satisfied because we have an unbalanced panel where our average number of observations per country is 10 which is less than the number of countries which is 12. Furthermore, we opt to estimate system General Method of Moments instead of the difference General Method of moments to overfitting instrumental variables.
[14] The implied marginal effect of crop area on forest cover in the Ivory Coast is similar to those derived by Osgood (1994) in Indonesia (4.25) and by López (1997) in Ghana (3.9) but it is difficult to accurately calculate the standard errors from these two studies.
[15] The significance and sign of our main coefficient estimates do not change when the expenditure variables, initial forest stock and price of investment are the only regressors and other controls are gradually added. The results of these regressions are available from the authors upon request.