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Deforestation, distribution and development

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Abstract

This paper investigates the role played by distributional factors in mediating the effects of growth and development on forest depletion in tropical developing countries. A key finding of the paper is that the distributional profile of a country significantly determines whether economic development will have either a positive or a negative effect on the rate of forest loss. In countries where levels of inequality are high, development will tend to exacerbate deforestation rates while in countries where distributional profiles are more egalitarian, the negative effects of growth and development on forest cover will be ameliorated.

Keywords: Deforestation; Poverty; Inequality; Development strategies; Economic growth; Environmental Kuznets curve

1. Introduction

The promotion of economic growth has formed the centerpiece of development planning and policymaking in the post-war period (IFAD, 1993; World Bank, 1990). In recent years, economists have complemented this focus on growth with attention to basic needs, investment in human capital formation, and environmental protection. Although not included in formal measures of economic output or GDP, the quality of a country's natural and human resource base is now recognized to be an important determinant affecting economic growth and the prospects for improved social welfare (Leonard, 1989; World Bank, 1990).

This shift in emphasis from strictly economic growth considerations toward issues of sustainability and welfare has emerged in response to increasing recognition of the problems now facing many developing countries. The first is the persistence of acute poverty. Despite the considerable economic progress made by developing societies in the post-war period, the absolute numbers of people living in poverty remains unacceptably high (Steer, 1992; World Bank, 1990; van der Gaag, 1991; IFAD, 1993). According to the 1990 World Bank's *Development Report* an estimated 1 billion people in the developing world live in poverty, nearly half of them in southeast Asia. International poverty profiles suggest that these people are likely to live in rural areas, to be in female-headed households, to be farmers or agricultural workers, to be landless or near-landless, and to be a member of an ethnic minority (World Bank, 1990; IFAD, 1993; Fields, 1980). In addition, wide intra-country disparities in income and wealth persist, not only within regions and countries of the developing world but between countries as well (World Bank, 1990; Fields, 1980; van der Gaag, 1991).

A second problem is the growing environmental crisis many developing countries now face. As Leonard (1989) notes, an increasing number of these poor are situated in marginal, resource-poor and ecologically degraded areas. Highly exploitative patterns of subsistence behavior in these areas lead to decreasing agricultural productivity due to environmental decay and resource depletion. Similarly, declining resource stocks and environmental quality undermine economic growth and development, exacerbating already deep social inequalities, and hindering the onset of the demographic transition.

A substantial economic literature exists devoted to understanding the role of poverty and inequality in economic growth. Similarly, a smaller and more recent body of literature exists on the relationship between

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the environment and economic growth. (Sections 2 and 3 below provide a very brief introduction to some of these works). However, most of the existing literature on economic development and the environment restricts itself to qualitative assessments of these relationships or merely speculates on the probable consequences for development arising from environmental degradation and excessive population growth (Myers, 1993). Despite the fact that distributional issues have been observed to have an important impact on economic growth and growth itself to have important consequences for the environment, there has been surprisingly little attempt to analyze the links between redistribution and the environment.

This paper will attempt to explore the nature of the relationship between the environment, poverty, inequality and economic growth. An important issue addressed is whether inequality and poverty have any significant mediating effect on observed relationships between growth and a key indicator of the decline in environmental quality: the rate of forest loss. In other words, does a country's distributional profile influence the relationship between economic development and a country's deforestation rate?

After a brief discussion outlining the dimensions of poverty and inequality in developing countries, the paper describes recent empirical evidence on the relationship between development and distribution and the environment. Following this discussion, the subsequent section will empirically analyze relationships using panel data from 48 developing countries. The estimated equations form the basis of a number of broad generalizations or "stylized facts" about the linkages between these key factors. Variables chosen for analysis in the study are predicted on the basis of the literature to influence deforestation outcomes, and as such, reflect key aspects of the development/deforestation/distribution nexus. It should be stressed at the outset that these relationships are not the only ones of importance influencing deforestation rates. Neither should it be assumed that the variables chosen for analysis are the only ones comprising this nexus. These relationships form part of a larger web of factors affecting forest loss, the relations and interrelations of which are highly complex. Despite this complexity (which makes it impossible to model these relationships adequately), the study aims to provide the basis for the development of more informative models and country-level investigations of these relationships in the future.

2. Patterns of poverty and inequality in developing countries

Empirical research on the distributional aspects of growth provides a number of implications for the present study:

(i) Much evidence points to a positive role for growth in reducing poverty; the incomes of the poor, in other words, have for the most part tended to rise with growth (Fields, 1989; World Bank, 1990). Countries that have made substantial progress in reducing the incidence of poverty have also been those in which income per capita has risen sharply (Fields, 1980, 1989). Although inter-temporal surveys of changes in distributions are lacking, this progress has been most pronounced in East Asia (recent financial crises notwithstanding). There is also some indication that income distributions have worsened in the past decade and a half in Latin America and sub-Saharan Africa (World Bank, 1990; Cardoso and Helwege, 1992; Fields, 1988b).

(ii) However, rapid economic growth is neither itself a necessary nor a sufficient condition for the reduction of poverty since slowly growing countries have achieved considerable progress in this sphere (van der Gaag, 1991; World Bank, 1990; Fields, 1980, 1989). Countries that have grown very slowly, such as Sri Lanka and much of sub-Saharan Africa, have only been able to raise incomes to any appreciable degree through strong redistributive efforts by government (World Bank, 1990). However, to paraphrase one expert, such policy efforts have been increasingly difficult for governments to implement in the absence of strong growth (Fields, 1980, 1988a).

(iii) Economic growth does not necessarily lead to either greater inequality or greater equality of distribution, although countries with initially egalitarian income distributions tend to grow faster than those with inegalitarian systems (Fields, 1989; Alesina and Perotti, 1994; Alesina and Rodrik, 1994; Persson and Tabellini, 1994; Birdsall et al., 1995). The initial level of income distribution appears to be a key factor in whether the poor will benefit from rapid growth. Further, growth has tended to reduce income inequality in the long run, but the effects of growth on income inequality have been less dramatic than on the alleviation of poverty (Fields, 1980, 1989).

(iv) None of the above trends should obscure the fact that rapid population growth has increased the absolute numbers of poor in many countries despite overall declines in the relative incidence of poverty (Fields, 1980, 1988a, 1989).

(v) International growth and development comparisons suggest that which distributional outcome occurs depends critically on the kind of public policy environment that governments choose to foster. The pattern of development appears to be as or more important, in other words, than the actual rate of growth in effecting positive distributional changes (Fields, 1980, 1988a, 1994; Ahluwalia, 1976). Summarizing the findings of a large number of international case studies, the World Bank (1990) concluded that countries that have exhibited "balanced growth" — that is, growth where all sectors and strata of society have benefitted — are those which have both grown rapidly and achieved sharp reductions in poverty in a short period of time. According to these studies, a key factor in the success of such countries has been their capacity to create labor-intensive employment opportunities for the mass of the poor while simultaneously fostering an appropriate environment in which new capital investment and skills development continually complement and reinforce one another (Barro, 1991; Persson and Tabellini, 1994; van der Gaag, 1991; World Bank, 1990; Birdsall et al., 1995).[1]

The available evidence also suggests that distributive measures are most effective in alleviating poverty when they encourage rapid expansion in non-agricultural sectors. Raising the purchasing power of rural regions through land reform, agricultural extension, and improvements in crop yields can raise effective demand in the countryside and prompt the expansion of non-farm pursuits. However, there appear to be limits on the extent to which raising productivity in the agricultural sector alone can create both the quantity and the quality of employment opportunities required for sustained economic growth (Fields, 1980).

3. Economic growth & patterns of environmental change

Recent empirical research suggests that the relationship between economic growth and environmental change exhibits a range of patterns, with many environmental indicators improving as incomes rise, some worsening, and others worsening and then improving (Steer, 1992). The growth of prosperity is also associated with improved living standards with respect to factors that bear directly on the quality of the environment (e.g. access to safe drinking water and sanitation) (Beckerman, 1992).

Several studies, for example, have consistently found a strong correlation between per capita income levels and improving environmental quality. This relationship is commonly referred to in the literature as the environmental Kuznets curve (EKC). Concentrations of sulfur dioxide and smoke, for instance, have been found to increase with per capita GDP at low levels of national income, decrease with per capita GDP between US$4000 and US$8000 (1985 dollars), and then level off (Grossman and Krueger, 1995; Selden and Song, 1994).

Similarly, Hettige et al. (1992) find an inverted U-shaped pattern holds for GDP and the toxic intensity (i.e. toxic releases per unit of production) of manufacturing industries. However, they also find that toxic emissions for this indicator depend heavily on the growth rate of income and the policy regime adopted by the country. For instance, fast-growing closed developing economies became significantly more toxic intensive in their manufacturing sectors during the 1970s, a trend that accelerated in the 1980s. In contrast, fast-growing, open economies experienced essentially toxic-neutral structural change in the 1970s and underwent a significant shift to less pollution-intensive structures in the 1980s. This same pattern appears to hold for slow and medium-growing open economies. Thus, while dirty industries expanded faster than cleaner industries in the developing world and faster than comparable industries in industrialized economies, not all developing countries exhibited growth in the toxic intensity of their emissions. Poor, closed but growing economies had the highest toxic intensity of their manufacturing mix, whereas the rapidly growing open higher income countries actually saw negative growth in the toxic intensity of their emissions.

Birdsall and Wheeler (1992) find a similar pattern holds in respect to intensity change in pollution by industry for Latin America. Results indicate pollution intensity to be lower (although still positive) at higher levels of per capita income between the 1960s and 1980s for all Latin America countries. Growth rates in the toxic intensity of emissions for closed economies that grew rapidly during this period were much higher than for fast-growing open economies.

Similarly, Wheeler and Martin (1992) find that the adoption of clean pulping technology is determined most significantly by a country's trade regime, with more open economies adopting clean technologies at a faster rate than closed economies. de Bruyn et al. (1998) use time-series data for four countries (USA, West Germany, Netherlands) on GDP and intensity of emissions of SO_2, NO_x and CO_2 a nd find a positive relationship (with the exception of SO_2 emissions in the Netherlands) between these indicators and economic growth. However, they also note that this positive effect can be counteracted by "the intensity of use effect", which becomes more important as income grows: in other words, technological and structural factors may counteract the positive impact of economic growth on emissions by reducing the intensity of pollution-generating materials use.

[1] The East Asian economies of Thailand, Korea, and Taiwan, Singapore and Hong Kong exemplify these patterns well. These countries are notable for their strong export-oriented labor-intensive growth strategies and high levels of investment in human capital development. These policies have been credited with creating rapid growth in the economy as a whole, raising wages and employment prospects for the mass of the population. In contrast, comparatively low levels of investment in human resources, coupled with the persistence of an import-substituting, industrial-urban bias in development, have been blamed in countries like Brazil, India and the Philippines, for the marginal and uneven participation of the poor across sectors and their relatively low skills level and productivity (Fields, 1980; Birdsall et al., 1995; WDR, 1990).

Kaufmann et al. (1998) find a U-shaped relationship between income and SO_2 concentrations, one they attribute to changes in energy use from fuels with a high sulfur content in the downward portion of the curve, to increases in energy consumption in the upward portion of the curve that outweigh the effects of shifting toward lower-sulfur content fuels. Conversely, when the spatial intensity of economic activity is substituted for income, they find an inverted U-shaped relationship holds. The latter, they argue, may be a more important factor in observed reductions in SO_2 concentrations than income alone. However, they caution that the eventual positive impact of spatial intensity of economic activity on SO_2 concentrations is vulnerable to increases in population, which in turn can offset any positive impacts associated with income gains.

Ambient levels of suspended particles and CO_2 emissions have been found to increase monotonically with GDP (Holtz-Eakin and Selden, 1995; Shafik, 1994. Unruh and Moomaw (1998) find this relationship to be non-linear and and punctuated by shocks that can change the trajectory of the relationship. They note that while CO_2 emissions have followed regular incremental paths as GDP grows, this relationship has also been subject to abrupt transitions, which appear to be correlated with exogenous factors that are independent of income growth (e.g. oil shocks).

Cropper and Griffiths (1994) find an inverted U-shaped relationship between per capita income and rates of deforestation for Africa and Latin America but not for Asia. In contrast, Koop and Tole (1999) find no such evidence, and conclude that the variability in government policies and other factors affecting land use patterns differ too significantly across countries for there to be commonalities in the structure of their forest quality indicators. Eakins (1997) examines the relationship between income and an aggregate indicator developed by the OECD. This index not only includes CO_2, SO_2, and NO_x emissions, energy intensity, sewage treatment, and solid waste generation, but other key environmental indicators, such as imports of timber and cork, threatened species of mammals and birds, kilometers of private road, number of protected areas, water use, and nitrate fertilizer application. The author finds no evidence to support the presence of an EKC.

In contrast to these studies, Rothman (1998) argues for a consumption-based approach to measuring environmental indicators. Production-based measures (e.g. pollution intensity of use) which dominate current research obscure: (a) the extent to which improvements in environmental quality are the result of both the spatial dislocation of dirty industries and the unsustainable demand for resources elsewhere; (b) the fact that most of the productive activities in higher-income countries, where environmental quality indicators have improved, are oriented primarily toward the satisfaction of consumer demand; (c) the full monetary costs and lifestyle changes needed to reverse environmental degradation when the focus is largely on the production of pollutants per economic unit. Accordingly, the author provides evidence based on a consumption indicator measuring ecological footprints/appropriated carrying capacity for 52 nations against GDP per capita. He finds no evidence of the presence of an EKC hypothesis for any functional form (e.g. linear, log–log and quadratic).

Similarly, Mason (1997) and Low and Yeats (1992) present evidence to suggest that with respect to (a) in particular, global gas reductions in some countries have been achieved largely through the displacement of industries to less-developed countries. With respect to (c) Suri and Chapman (1998) make the additional observation that, the issue of the appropriate measure aside, studies finding an EKC are misleading since the production of increasingly non-energy use intensive goods which can be observed as incomes rise obscures the fact that many of the activities fueling economic growth require large amounts of energy-intensive inputs. For this reason, the authors argue that a better measure of environmental stress is total commercial energy consumption. Using this measure, the authors find that the nature of the EKC (i.e. its inverted-U shape) can be accounted for by examining energy use at its source: In industrializing countries, exports of manufactured goods account for the upward sloping portion of the EKC, and in industrialized countries, imports of manufactured goods, the downward sloping portion. However, they caution that the estimated turning point for energy consumption lies well outside the sample range, particularly when trade effects are accounted for.

Finally, Torras and Boyce (1998) empirically analyze the relationship between air and water quality indicators known to improve with income. They find that in many cases it is not economic growth per se behind observed relationships between income and the environment. Changes in the distribution of income, and in particular, increases in income which enhance the power of the average citizen to demand environmental protection, appear to be key. The authors find that literacy, political rights and civil liberties measures are strong predictors of pollution levels in low-income countries. Improvements in these environmental indicators are associated with less pollution at low income levels where the generally strong relationship between income and environmental quality as measured by these indicators weakens greatly. Income inequality as measured by the Gini ratio, was found to have less consistent effects on environmental quality indicators. Greater income inequality was associated with more pollution and less access to safe water, heavy particles and dissolved oxygen, and appeared to increase with greater income inequality in the low-income countries. Results were weaker for higher-income countries but similar patterns were found, suggesting that power is a particularly important factor influencing environmental quality when income is very low. The authors also report evidence to suggest that for some measures greater inequality exacerbates observed relationships between income and the environment.

4. Distribution, development and deforestation: sources of testable hypotheses

Differences in the nature of the relationships between economic growth and indicators of environmental quality may reflect differences in policies toward certain indicators, the costs of environmental degradation and its abatement, and/or variations in the production structures of countries at different levels of economic development. As economic activities shift away from agriculture to industry and then again to services and high-tech industries, "the intensity of environmental services used up in the production of a unit of GDP declines" (Radetzki, 1992). Other processes accompanying this shift can also affect the level of pollution and intensity of natural resource use: the extension of property rights to open access reserves; the diffusion of new technologies; greater efficiency in the use of resources prompted by greater trade openness; the inclusion of environmental protection objectives in the political process; growing public valuation of and awareness of the environment; and so on (Radetzki, 1992; Grossman and Krueger, 1995; Birdsall and Wheeler, 1992; Behgin et al., 1994; Wheeler 1996). With respect to the latter factor, it has been consistently noted in the literature (e.g. see Rothman, 1998) that the kind of environmental problems that appear to improve with income (generally, at the middle income level) tend to be those which can best be described as being non-separable in space and time. These tend to have localized impacts (e.g. sewage pollution) with observable health effects and do not require trans-national cooperation to address (e.g. global warming).[2]

However, as Steer (1992) and Grossman and Krueger (1995) note, there is nothing inevitable about such processes. Economic growth may or may not lead to improved environmental quality and sustainability in the use of natural resources. The kind of policy regime that governments choose to foster — the land use and environmental protection policies they implement and the sectors and strata they choose to target for development — will also play a critical role in which environmental outcome will dominate, irrespective of the technological and structural effects induced by economic growth (Steer, 1992).

An important factor influencing a country's environment-development trajectory is the extent to which economic expansion alleviates poverty pressures on the environment and promotes environmental awareness. Whether this happens will depend greatly on whether governments pursue development policies that: enable the poor to benefit from economic growth, lead to better provision of government services, improve agricultural and industrial productivity, and encourage technological innovation. As discussed in Section 1, it is quite possible to raise aggregate income without appreciably changing the living standards of the mass of the population. (However, as noted, achieving or sustaining progress in redistribution is difficult in the absence of robust growth.)

Thus, environmental degradation may worsen if distributive policies marginalize the poor despite the fact that the economy may be growing quickly (Steer, 1992; IFAD, 1993). In addition, environmental quality may worsen despite other positive spin-offs for the environment arising from structural changes induced by economic growth in consumption, production and social welfare.

An important question is whether social welfare policy may have an important mediating effect on environmental outcomes of economic growth. In other words, to what degree, if any, are the overall effects of economic expansion on the environment influenced by a country's distributive policies? The next section will attempt to answer this question by determining the role played by poverty and inequality in mediating deforestation rates in developing countries. It is hypothesized that while economic growth may lead to deforestation as output expands, the scale of this exploitation may be exacerbated by social conditions. For example, large numbers of impoverished people denied access to resources, particularly land, can exacerbate already strong pressures on forests arising from the overall growth in the scale of economic activity. High levels of poverty and inequality may also accelerate forest decline by hindering the transition to demographic stability. Worsening poverty and inequality may also perpetuate reliance on the resource base, thereby exacerbating resource shortages and lessening environmental quality.

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[2] Note also that research suggesting the presence of a positive relationship between some environmental indicators and economic growth has tended to ignore issues of carrying capacity and ecological resiliancy. Arrow et al. (1995) and Kaufmann and Cleveland (1995) observe, for example, that current studies have utilized data related to resource stocks or to pollution emissions but do not consider possible synergistic environmental effects or consequences for the renewability of the resource base arising from such degradation. Thus, it is quite conceivable that the environment may actually be deteriorating as some environmental quality indicators are showing steady improvement. Long-run sustainability, in other words, depends fundamentally on the capacity of the environmental resource to renew itself and absorb and process waste.

Similarly, Stern et al. (1996) argue that the actual indicator used to measure environmental quality may or may not reveal a state of improvement. For example, ambient levels of SO_2, and CO_2, NO_x do not tell us anything about the level of acid deposition agricultural ecosystems are facing.

A poor welfare profile may also affect forest cover in other, less direct ways, by undermining any positive benefits accruing to the environment arising from economic or institutional changes elsewhere. Similarly, by contributing to political instability, poverty and inequality can undermine the security of property rights associated with sustainable resource use — and ultimately — economic growth itself (Keefer and Knack, 1995).

In short, a country in which growth is not accompanied by the alleviation of poverty or inequality would be expected to have higher deforestation rates than one characterized by more balanced and equitable growth that improves the lives of the mass of the poor. Deforestation, in other words, would be expected to be higher in countries like Brazil and the Philippines, where growth has not been accompanied by the eradication of poverty and/or inequality to any significant degree. Countries in which growth has either been slow or has stagnated but in which governments have made deliberate efforts to distribute public resources (e.g. Sri Lanka, Tanzania) should have lower deforestation rates than those countries where poor growth performance has also been matched by a poor distributive profile (e.g. India, Haiti). Those countries that have managed to grow fairly quickly (e.g. Jamaica, Bangladesh) but have failed nevertheless to achieve appreciable reductions in levels of poverty or inequality, would be expected to have higher rates of deforestation than those countries where growth has been more balanced (e.g. Malaysia, Singapore, Korea).

5. Empirical analysis

This section empirically investigates the relative impact of distributional factors on the relationship between economic growth, development and deforestation. We begin with a standard panel data model for deforestation (e.g. Cropper and Griffiths, 1994; Koop and Tole, 1999). Deforestation is defined in this study as the percentage annual decrease in forest area. Data on forest cover loss for 48 tropical developing countries are derived from the FAO *Production Yearbook* for various years between the period, 1961–1992. Although the FAO Production data is not the only existing source of global forest data, it is the most comprehensive, covering more countries and spanning a longer period than any other source (Allen and Barnes, 1985). This deforestation measure is based on a definition of forest cover that includes all woody vegetation. More specifically, forests and woodland refer to all land under natural or planted stands of trees, regardless of productivity, in addition to land that has been cleared of forests but will be reforested in the near future. This broad definition largely avoids problems associated with inconsistencies in definition arising from the use of more restrictive forest definitions.[3]

Although all types of forest cover are represented by the data, we include in this study only developing countries whose predominant ecosystems are tropical. Tropical forest ecosystems dominate the developing world. It is their progressive destruction more than that of any other ecosystem, which is causing the greatest international alarm in view of the rapid rate at which they are being depleted, their unique biodiversity, and the important ecological and material contributions they make to human welfare.[4]

The level of economic development and rate of economic growth are measured by GDP per capita and the % change in GDP per capita. Both are from the commonly used Penn World Table, which adjusts to a common set of international prices. Two demographic measures — population density and change in population — important for their impacts on the consumption and production processes that fuel economic growth, poverty and environmental degradation — are also included in the analysis. Population density is measured as the number of people per hectare of land area, and population growth, as the percentage annual increase in total population. Both indicators are derived from FAO Production Data and the Penn Word Table, respectively.

The data above (i.e. deforestation, GDP, GDP growth, population growth) are panel data (i.e. are both across countries and over time). Since we also wish to include distributional variables, for which data are not usually available in time-series form (income or land inequality measures are typically based on government surveys which are carried out at most once a decade), we cannot use a standard panel data framework, but rather choose a model of the form

$$y_{it} = \alpha_i + \sum_{j=1}^{4} \beta_j x_{jit} + \sum_{j=1}^{4} \gamma_j d_i x_{jit'}$$

[3] A drawback of the data is that it relies heavily on individual government surveys to supply information. Another drawback is that the data does not distinguish between forest types. Thus, even land which has lost its primary forest cover but has been replanted with monocultural tree plantations is included in the definition of forest cover. So, too, are heavily degraded forests, which to all intents and purposes have ceased to resemble viable ecosystems. Finally, studies measuring the relationship between growth and forest cover depletion may underestimate the contribution of development to the deforestation process, since the amount of forest cover at any given period of time is always a by-product of previous land-clearance activities (see Pearce and Brown, 1994, for a discussion of the methodological issues surrounding the measurement of tropical forests).

[4] In this paper we adopt the FAO/UNEP 1994 definition of tropical. Tropical forests encompass a wide variety of ecosystems (e.g. evergreen, semi-evergreen, semi-deciduous, premontane, woodlands, alpine, savannah, and shrub) situated in countries receiving between 200 to 20,000 mm of rainfall annually (see WRI, 1994–1995).

where y_{it} is deforestation in country i at time t, x_{jit} is explanatory variable j in country i at time t (i.e. $j=1$ indicates GDP per capita, $j=2$ GDP growth, $j=3$ population density and $j=4$ population growth) and d_i is a distributional measure for country i. Note that d_i has only an i subscript, indicating that we have only one data point per country. We consider for our distributional variables (i.e. d_i) one measure of income inequality, the Gini coefficient (GINI) of income, and two of land inequality, the Gini coefficient for land (LANDGINI) and the percentage of land held by the top 20% of landowners (LANDT20), respectively. This last measure is included since large landholdings are typically more accurately measured than are smallholdings. All these variables are taken from IFAD (1993). Higher values for these variables indicate a greater degree of inequality. A list of countries, years, and data definitions are given in the appendices. Summary statistics for all variables are given in Table 3 in Appendix B.

In practice, distributional issues likely reflect underlying economic/social/political structures that change only slowly over time so that the information loss involved in not having time-series data for distributional variables is probably quite small.[5]

Note also that the marginal effects (i.e. the effect on deforestation of a one unit change in an explanatory variable) of explanatory variable j is $\beta_j + \gamma_j d_i$. This implies, for instance, that the effect of increasing GDP per capita on deforestation can vary across countries depending on the value of the distributional variable. In short, this model explicitly addresses the question of interest in this study, namely, "How do distributional issues affect the deforestation/development relationship?".

Table 4 in Appendix B provides results from fixed effects estimation of the model with each of the three different distributional measures. To aid in interpretation, we subtract the mean from each of the distributional variables so that a country, for instance, with an average level of income inequality, for instance, will have GINI = 0.

One implication of this approach is that the first four rows of estimates (i.e. those labelled GDP, GDP growth, Pop. density and Pop. Growth) can be interpreted as measuring the effects of these variables on deforestation for a country with an average amount of inequality. Looking at these four rows, we find a reasonably consistent picture for all three of our distributional measures. That is, GDP and population growth have little effect on deforestation for countries with an average amount of inequality. However, GDP growth is negatively and population density positively, associated with deforestation for these average countries. This latter result is not surprising: higher population density is associated with more deforestation. The former result is perhaps less expected: faster GDP growth is associated with less deforestation.

The numbers in the bottom half of Table 4 are the most important ones in that they illustrate how distributional considerations affect deforestation/development or deforestation/demographic relationships. Although there are some conflicts across distributional measures (i.e. the income and land inequality measures yield somewhat different results), the general pattern of the results which are statistically significant is consistent with the hypothesis of this paper. That is, more inequality causes the deforestation/development relationship to worsen.

If we look, for instance, at the results for GDP for the land inequality measures, we find that for countries with average levels of inequality, GDP seems to have no effect on deforestation (i.e. the marginal effect, $\beta_1 + \gamma_1 d_i$, reduces to β_1 since $d_i = 0$ for these average countries; and the β_1 coefficient is statistically insignificant). However, for countries with above average levels of inequality $d_i > 0$ and the marginal effect for GDP now becomes significantly positive. In other words, if we consider countries with a high degree of land inequality, GDP and deforestation are positively related (i.e. more GDP is associated with more deforestation). In contrast, in the case of those countries characterized by greater equality in their distribution of land, d_i is negative and hence the marginal effect of GDP on deforestation is significantly negative. In other words, in more equal countries, more GDP is associated with less deforestation.

A similar, but statistically weaker, story can be told for the income inequality measure. That is, higher levels of inequality tend to worsen the deforestation/GDP growth and deforestation/population growth relationships. Conversely, lower levels of inequality improve these relationships.[6]

6. Conclusion

This paper has sought to establish some key stylized facts about the role of distribution in mediating the effects of development and growth on forest depletion in tropical developing countries. A key finding of the paper is that distributional profile is a significant determinant

[5] Note also that statistical tests indicate that the use of a fixed effects specification is required (i.e. the intercept of the regression relationship, α_i, varies across countries). However, such a regression specification excludes the use of d_i as a separate explanatory variable, which can only be included by allowing it to interact with the x_{jit}, s. (see Greene, 1997, chapter 14, for a discussion of estimation and testing with panel data models). Formally, we use fixed effects estimation for unbalanced panels.

[6] A mathematical way of conceptualizing these results is to note that all statistically significant coefficients which involve any of the distribution variables are positive.

of whether economic development will have either a positive or a negative effect on the rate of forest depletion. It appears that in countries where levels of inequality are high, development will tend to exacerbate deforestation rates. Conversely, in countries where distributional profiles are above the average for egalitarianism, distributional factors will tend to have a positive impact, ameliorating the negative effects of growth and development outcomes on forest cover. The more egalitarian the country, in other words, the less deforestation. The role of distributional factors appears to work independently of the strong positive effect observed for population pressures on deforestation rates as well as the negative (albeit much weaker) effect of fast growth on deforestation (i.e. fast growth rates are associated with less forest loss).

We can now supplement the study's findings with those of the economic literature on poverty, inequality and development discussed in Section 2. According to this literature, more egalitarian countries also tend to grow faster. This study has demonstrated that the more egalitarian a country is the less deforestation it is likely to have; in addition, the faster a country grows the less deforestation. However, irrespective of whether countries exhibit fast or slow growth, distributional factors will play a significant role in determining the severity of the impacts of economic development on the environment.

This strong but varying role for distribution in mediating development/deforestation outcomes across different income levels and rates of economic growth may also explain the contradictory findings of the environmental Kuznets literature. As noted, some environmental indicators appear to worsen and then improve with economic growth; others appear to worsen or to improve steadily; others show no discernible pattern. It could be that, among other factors, variations in environmental trajectories may relate to differences in distributional factors across countries, with some environmental quality indicators, in other words, being more susceptible to distributional influences than others. Forests, unlike some indicators (e.g. air quality), are closely tied to the distribution of land. Further, being a significant factor of production in rural areas, land is also a major source of income. If, as many studies suggest, certain air and water quality indicators may improve with income this may reflect the political reality that government intervention in these areas is less contentious than is distributing land or income. Indeed, as the history of developing societies has repeatedly shown, such reforms have often proved to be as difficult to implement as they are rare.

Table 2
List of countries with years of availability

Bangladesh	61–92	Grenada	84–90	Niger	61–89
Belize	80–92	Guatemala	61–92	Nigeria	61–92
Bolivia	61–92	Guyana	61–90	Pakistan	61–92
Botswana	61–89	Haiti	61–89	Panama	61–92
Brazil	61–92	Honduras	61–92	Paraguay	61–92
Cameroon	61–92	India	61–92	Peru	61–92
Cape Verde	61–92	Indonesia	61–92	Philippines	61–92
Colombia	61–92	Jamaica	61–91	Rwanda	61–92
Costa Rica	61–92	Kenya	61–92	Sierra Leone	61–92
Cote d'Ivoire	61–92	Liberia	61–86	Sri Lanka	61–92
Dominican Rep.	61–92	Malawi	61–92	Suriname	61–89
Ecuador	61–92	Malaysia	61–92	Thailand	61–92
El Salvador	61–92	Mauritania	61–92	Togo	61–92
Ethiopia	61–86	Mexico	61–92	Trinidad & Tob.	61–91
Gambia	61–90	Myanmar	61–89	Uganda	61–92
Ghana	61–92	Nepal	61–86	Zambia	61–91

Table 3

	Mean	SD
% decrease in forest cover	0.01	0.02
GDP per capita ($000)	1.73	1.70
% increase in GDP	0.01	0.07
People per hectare of land	0.64	1.02
% increase in population	0.03	0.02
% land held by top 20%	0.64	0.17
Gini coefficient for land	0.53	0.15
Gini coefficient for income	0.46	0.84

Table 1 [a]

Region	Number (millions)	Headcount index (%)	Life expectancy (years)	Under five mortality (per '000)	Poverty gap[b]	Net primary enrollment rate
Sub-Saharan Africa	180	47	50	196	11	56
East Asia	280	20	67	96	1	96
South Asia	520	51	56	172	10	74
Middle East & North Africa	60	31	61	148	2	75
Latin America & Caribbean	70	19	66	75	1	92
TOTAL	1110	25	60	98	2.5	78.6

[a] Adopted From WDR (1990, Table 2.1).
[b] Defined as the aggregate income shortfall of the poor as a % of aggregate consumption.

Table 4[a]

	Measure of distribution		
	Land owned by top 20%	Land gini	Income gini
GDP	− 0.001 (0.001)	− 0.001 (0.001)	− 0.001 (0.001)
GDP growth	− 0.014[b] (0.008)	− 0.014[b] (0.008)	− 0.010[c] (0.008)
Pop. density	0.004[b] (0.002)	0.005[d] (0.002)	0.007[d] (0.003)
Pop. growth	0.061 (0.057)	0.065 (0.061)	− 0.003 (0.061)
GDP × distribution	0.023[d] (0.009)	0.026[d] (0.012)	0.012 (0.017)
GDP growth × distribution	− 0.032 (0.045)	− 0.046 (0.056)	0.110[c] (0.087)
Pop. density × density	− 0.006 (0.023)	0.003 (0.030)	0.031 (0.033)
Pop. growth × distribution	− 0.071 (0.355)	− 0.059 (0.562)	0.547[c] (0.447)

[a]Errors in parentheses.
[b]Indicates significance at the 10% level.
[c]Indicates significance at the 20% level.
[d]Indicates significance at the 5% level.

Appendix A

The regional poverty profiles are given in Table 1.

Appendix B. Data sources

The deforestation data is obtained from the FAO's Agrostat-PC land use and input diskette and uses the study's forest and woodland variable. This source is also used to obtain total land area for calculating population density. Economic variables are from the Penn World Table (version 5-6), a commonly used data source which corrects GDP figures for cross-country price differences to ensure that numbers are comparable across countries. Data for the study's distributional variables, income, land inequality and welfare are from IFAD (1993) (see Table 2).

Appendix C. Empirical results

Summary statistics for data are shown in Table 3 and the regression results in Table 4.

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