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THE EFFECTS OF REDD FUNDING ON DEFORESTATION

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The main objective of this paper is to see how funding from the Reduced Emission from Deforestation and forest Degradation program (REDD) effects deforestation in tropical countries. This paper focuses on determinates of deforestation such as GDP, population, agricultural land expansion, agricultural production, and debt. These determinates of deforestation are used in a modified Environmental Kuznets Curve that measures the degree of forestation, as opposed to the degree of deforestation/degradation. This model is then applied to an unbalanced panel data set of 181 countries from 2006 to 2012. The paper also examines property rights as a time-invariant country-specific effect. The main findings of this paper is that REDD funding does have a positive relationship with forestation in tropical countries. It also supports the Environmental Kuznets Curve theory that an increase in the GDP per capita leads to decreased per capita forestation.

JEL classifications: O11, O13, O44, Q23

Key words: Agriculture, Deforestation, Economic Development, Environment, Environmental Kuznets Curve, Forest, Forestry, Natural Resource, Property rights

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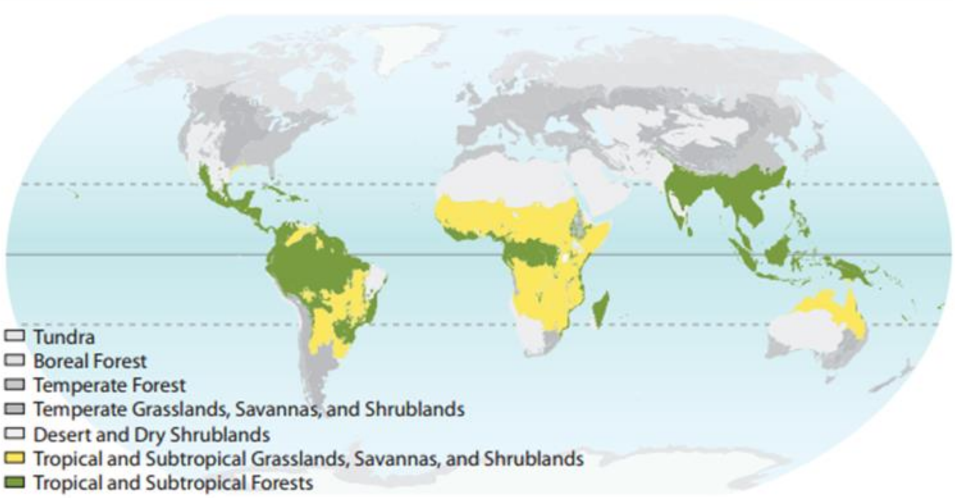
I. Introduction

Deforestation is the permanent destruction or removal of forest land. The United Nations' Food and Agricultural Organization (FAO) estimate a global net loss of around 18 million acers (7.3 million hectors) of forest land each year. This estimated loss in forest land is nearly equal in size to the entire country of Panama (Szalay 2013). Deforestation is a pressing concern, because tropical forests are the home to much of the world's biodiversity and are instrumental in reducing global climate change (Faria and Almeida 2013, Barbier 2004). The Intergovernmental Panel on Climate Change (IPCC) estimates that deforestation accounts for roughly 17% of the total annual carbon released into the atmosphere each year (Solomon 2007). Carbon emissions are considered to be a leading contributor to global climate change that can wreak havoc on the ecosystem. This has prompted recent research to argue that reduced deforestation can be a cost effective way to mitigate global climate change (Kinderman 2008). Global forestation remains a pressing concern because the majority of the world's forests, for example the Amazon, lie in the tropical zone of

Figure 1 Map of the World's Terrestrial Biomes



This map highlights the world's tropical and subtropical forests (dark green) and tropical and subtropical grasslands, savannas, and shrublands (yellow).

Source: UNEP-GRID-Arendal 2009; Olson et al. 2001.

the globe, near the equator where many poor developing countries are located. The tropical zone is shown in figure 1 (Elias 2011). These countries tend to see higher rates of deforestation as compared to the rest of the world.

In this paper, I examine how institutions, such as the Reduced Emission from Deforestation and forest Degradation program (REDD), can connect developed countries to fund developing countries in order to help reduce deforestation. REDD is dedicated to developing programs and policies to reduce deforestation on a global level, but mainly focuses its resources and funding toward developing countries since this is where the majority of deforestation tends to occur. The primary goal of this paper is to determine whether REDD funding has an effect in reducing deforestation in tropical countries. By using a modified Environmental Kuznets Curve (EKC) model, I examine how REDD funding and other determinants of deforestation effect forestation. This model is applied to an unbalanced panel data set of 181 countries from 2006 to 2012.

II. Literature review

A. Determinates of Deforestation

There are two strands of literature that address the determinants of deforestation. The first strand looks at deforestation on a country-specific level, while another strand addresses regional causes of deforestation. Both are important because deforestation is a complex process, making it difficult to pinpoint specific causal factors. Most literature agrees that agricultural land expansion is a key cause of deforestation. Agricultural land is one of the greatest sources of wealth for developing countries. However, agricultural expansion is one of the primary causes of deforestation because there is usually a tradeoff between agricultural land use and forest land use. (Barbier 2004). As agricultural production increases, deforestation is expected to increase because a country's total land area is fixed. According to the Food and Agriculture Organization (2001) and the 2000 Global Forest Resource Assessment, nearly 50% of total forest area change is due to conversion to agricultural land. Latin America has the largest tropical forests in the world, much of which are found in the Amazon, and has also been the world leader in deforestation (Elias 2011). A large part of the deforestation found in Latin America is, in part, due to agricultural expansion. From 1980 to 1990, South and Central America combined have seen an increase in roughly 7.5 million hectares of crop land (Elias 2011). A majority of this agricultural expansion comes by expanding into forest areas. The profitability of agricultural land drives conversion of agricultural land expansion, whereas when the demand for agriculture goes up, so does the demand for agricultural land. (Shafik 1994, Chomitz and Gray 1996, Cropper et al. 1999, Barbier 2004, Culas 2006, Faria and Almeida 2013). Poorer countries tend to exploit their natural resources in order to attempt to improve their standard of living (Shafik 1994). By converting forest land to agricultural land, poorer countries can increase their wealth in the short-term in exchange for inflicting environmental degradation in the long-run.

Other causes of deforestation include GDP growth and population growth. Both GDP and population growth tend to lead to increased resource extraction within an area. The Environmental Kuznets Curve hypothesis supports that an increase in GDP will lead to an increase in environmental degradation. Larger populations result in an increase in environment degradation because an increase in the number of people in an area will result in an increase in the demand for resources (Mather and Needle 2000, Faria and Almeida 2013). Other causes of deforestation discussed in the literature include: property rights, road infrastructure, and national debt. Countries that have better defined property rights and well enforced land titles tend to see better management of forest land. This occurs because when land rights are protected, land owners are likely to see a return on their investment and therefore have increased incentive to take care of their forests (Palo and Lehto 1996). Roads and infrastructure of a country allow for easier access to forests. This allows for efficient extraction of forests in areas that would not have been accessible otherwise (De Luca 2007). Debt plays a role in deforestation when struggling countries enter into debt-for-nature swaps where they exploit natural resources in order to pay back immediate debt constraints (Kahn and McDonald 1995, Culas 2006).

GDP growth is found to be a significant underlying cause of deforestation. Faria and Almeida (2013) conduct a study of the relationship between openness to trade, measured as the sum of imports and exports as a proportion of GDP, and deforestation in the Brazilian Amazon. The article uses panel data of 732 different municipalities, from years 2000-2007. This analysis focuses on determinants of deforestation, one of which is GDP. What Faria and Almeida find is that as deforestation increases, GDP increases, but the square of GDP decreases. These results coincide with the Environmental Kuznets Curve Hypothesis, which states that as income rises, environmental degradation will also rise until a threshold at which increased income correlates with a decrease in environmental degradation.

Population growth is usually used as a determinant of environmental change because larger populations will have a greater impact on the environment than smaller ones (Mather and Needle 2000). Nath and Mwchahary (2012) examine the effects of population on deforestation specifically within India from 1977-2007, and found that population increase is a primary cause of deforestation. This idea is supported on a global level by Palo and Lehto (1996) who use panel data from 1980-1990 and find that a 1% increase in population will lead to a .75% decrease in forest area all else equal.

Historically, when roads are placed near forest areas, deforestation speeds up (De Luca 2007). This is because road development creates easier access to untapped forest lands that would otherwise not be cost effective to harvest. De Luca (2007) hypothesizes that road development will have a positive relationship with deforestation by arguing that road development makes agricultural products and forest products more profitable to produce further away from markets than it would be without. Cropper et al. (1999) examines the impacts of road density and population on deforestation in Thailand from 1976-1989; and finds that in southern Thailand, a 1% increase in road density reduced the forest area by almost 1.5% all else equal. This supports that road development is an underlying factor of deforestation. Road development into forest lands tends to create a tradeoff between economic development and deforestation (Chomitz and Gray 1996). Therefore, the relationship between the roads and deforestation of a country will likely be similar to the relationship between GDP and deforestation.

Culas (2006) uses empirical evidence derived from developing countries in the tropical zone to show the impact of debt on deforestation. The author hypothesizes that deforestation occurs through clearing land for agricultural use in order to pay off current debt. In many developing countries, a high foreign debt can lead to a debt crises in which the country's government cannot collect enough tax revenue in order to pay back their debt. In this situation, the developing country may turn to exploiting their natural resources in order to deal with foreign debt in the short run. Culas (2006) finds that for every one million dollars in external debt for a country, approximately 7.5 hectares of forest is lost. Kahn and McDonald (1995) support that debt is a source of deforestation pressure, by examining data from multiple countries. Their results indicate that one billion dollar reduction in a country's debt will lead to a reduced 930 square km of annual deforestation. Both studies' estimates support that there is a positive relationship between debt and deforestation.

B. International Agreements

The first international agreement designed to combat global climate change was the Kyoto Protocol of 1997, which created carbon markets and new clean development mechanisms (Gupta 2007). The carbon markets that were created from the Kyoto Protocol function by having countries establish a limit on the amount of carbon that they are willing to emit each year. Carbon credits are then created based on this limit. All of the firms within a country are then allotted a certain number of credits, and can trade leftover credits on the market for cash exchanges. This allowance-based system is known as cap-and-trade (Hamilton et al. 2007). Since firms that do not use up all of their allotted carbon credits can sell excess credits in the market, a financial incentive is created for firms to invest in long-term clean technologies. However, one weakness of the Kyoto Protocol was that it did not take deforestation into consideration (Gupta 2007). Deforestation accounts for nearly one-fifth of the total annual carbon emissions released into the atmosphere. Recent researchers argue that a reduction in carbon emissions through avoided deforestation or reforestation could be a cost effective way to help mitigate global climate change (Rosea et al. 2007; Stern 2008).

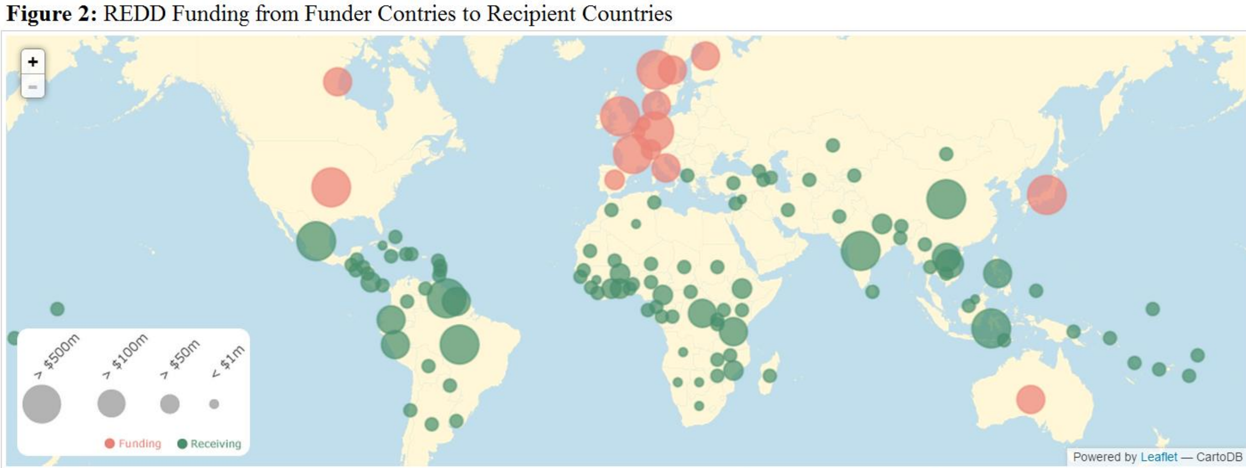
In response to the shortcoming of the Kyoto Protocol with regards to addressing deforestation, other programs have since developed that specifically target reduced deforestation as a means to mitigate global carbon emissions. One of the most notable programs is the, United Nation's UN-REDD program, the Reduced Emission from Deforestation and forest Degradation program (REDD) which was launched in 2008. In addition to reducing emissions from deforestation and forest degradation, REDD aims to promote forest management by protecting and increasing forest carbon stores (Kerr 2013). Forest carbon stores are developed when trees take in carbon from the atmosphere to create oxygen, and are released when the tree is destroyed.

REDD+, an extension of REDD, is a collaborative effort between the United Nations and the World Bank to try and not only reduce emissions through avoided deforestation, but to also create economic incentives to promote reforestation and afforestation. REDD+ activities are generally categorized as projects, policies, or sector activities (Madeira 2008). These projects create credits by maintaining carbon stocks in forest land. Many of these projects also focus on protecting threatened forest land by creating parks and protected reservations. REDD+ policies focus on altering land-use policies that encourage deforestation. For instance, policies that favor agricultural expansion can create incentives for deforestation. Lastly, sectoral activities focus on reducing deforestation rates country-wide by implementing rules such as emission caps (Madeira 2008). These REDD activities are used to create voluntary carbon markets and encourage developing countries to develop emission caps. They also create a pay-for-performance system in which developed countries fund developing countries based on performance in reducing deforestation (Lubowski and Rose 2013). It is the pay-for-performance part of REDD policy that this paper will be examining.

A pay-for-performance international agreement between a developed donor country and a developing recipient country is established when the recipient country agrees to reduce deforestation. This is often a result-based agreement, where the recipient country must prove that it is actively reducing deforestation in order to continue to receive funding. Satellite imaging of forest coverage makes it easier to measure deforestation over time, and consequently provided data which donor countries can use to monitor a recipient country’s performance (Kerr 2013). One of the most successful cases of pay-for-performance agreements was the agreement between

Norway and Brazil from 2004-2009. In this agreement, the government of Norway contributed approximately 1 billion dollars through deforestation reduction funds to Brazil. This in part, resulted in a 75% decrease in Brazil's overall deforestation in the Amazon (Lubowski and Rose 2013). The funds received from Norway helped prevent deforestation by putting in place and maintaining policies that protect sectors of forest land (Soares-Filhoa 2010). The REDD program acts as a third party that connects developed countries with developing countries to establish agreements to reduce deforestation. Figure 2 is taken from the Voluntary REDD database and shows a map of the donors (in orange) and the recipients (in green), in addition to the magnitudes of those funds (shown by the sizes of the circles). These agreements are similar to the agreement between Norway and Brazil in that they provide a way for a developed country to offer incentives to developing countries to try and reduce deforestation. This paper will take the information of the REDD funding and apply it to a model of deforestation to determine if REDD funding helps mitigate deforestation across regions.

Figure 2: REDD Funding from Funder Contries to Recipient Countries



Funders (orange) and recipients (green) of REDD+ financial contributions, as reported by funders. Click on the circles above to view REDD+ financing provided/received for a given country.

III. Theoretical Framework

Developing countries tend to place higher value on resource extraction than on preserving the environment (Faria and Almeida 2013). The environmental Kuznets hypothesis suggests that there is a correlation between environmental degradation and a country's income. This hypothesis suggests that environmental degradation will increase as income rises, up until a point at which higher income will result in improved environmental quality (Dinda 2004). This relationship is shown by an inverted U-shaped curve, as shown in Figure 3. The idea behind this hypothesis is that in order to generate more income, the people of a country will extract resources faster than those resources have time to regenerate. However, the explanation for the eventual downward slope of the curve is that when a country reaches a more stable economic level, the people of the country are no longer struggling to survive. Thus, they are able to take an interest in the country's overall environmental impact and begin to reduce the country's level of environmental degradation (Dinda 2004). As a country becomes more developed, the way that the people of the country value forest land begins to change. As people value forests more, they begin to act differently towards the country's natural forests which results in new regulations that

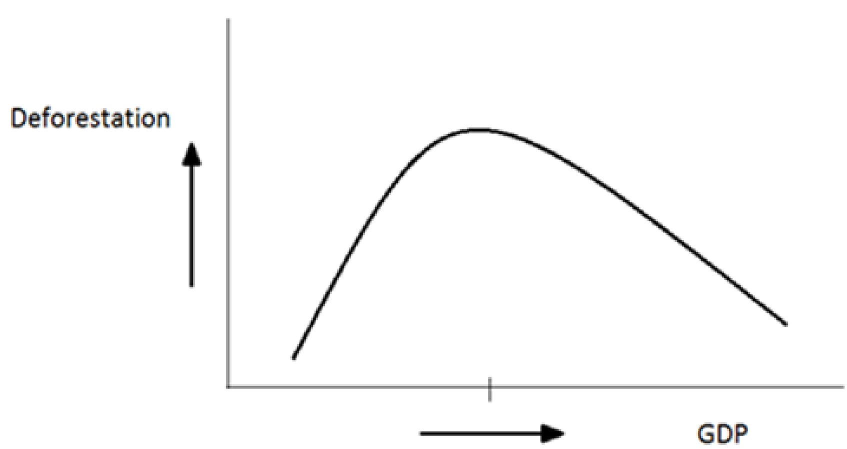


Figure 3 Enmironmental Kuznets Curve (With Deforestation)

promote forest preservation (Dinda 2004).

The Environmental Kuznets Curve (EKC) applies to deforestation, a measure of environmental degradation, because forests are a valuable natural resource which can generate revenue for developing countries. Countries that over extract their natural forests will likely see an increase in GDP due to exportation of forest products. This increase in GDP will result in a steep increase in deforestation, as expressed by the slope of the curve in figure 3. However, according to the EKC theory, once a country achieves a threshold income, that country will begin to take an interest in preserving and reforesting their natural forests. At this point, the

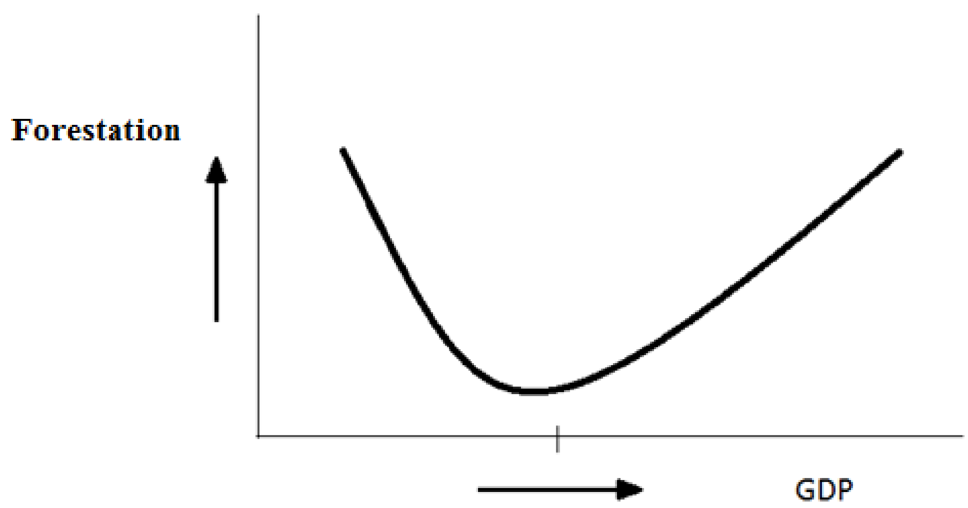


Figure 4 Environmental Kuznets Curve (With Forestation)

country's income will continue to go up, but there will be a gradual decline in forest degradation.

In the model for this paper, forestation is used in place of deforestation, due to the unavailability of data measuring deforestation. Forestation is measured by the total land area covered by forests. Since deforestation and forestation are inversely related, a negative change in forest area will indicate that deforestation is occurring. In the EKC, the curve will become U-shaped when using forestation instead of deforestation. In figure 4, the signs for GDP and the square of GDP are inverse of those for the traditional EKC model. Therefore, as forestation increases, GDP will decrease while GDP squared will increase. This is consistent with the traditional EKC, the only difference being the substitution of measuring forestation instead of deforestation. The interpretation of the EKC remains the same.

Another trend that exists between developing countries that can lead to forest degradation is the lacking of property right enforcement (Ferreira 2004). A property right is defined as the exclusive right to decide how a specific resource is used (Henderson 2008). Without proper enforcement of property rights, resources are managed inefficiently because no one person or institution has the exclusive right to decide how a resource is used. Secure property rights promote efficient management of forests and will decrease deforestation because those who own the land title have a vested interest to reinvest in the forest land for future profit (Mendelsohn 1994). In other words, those extracting the resources from a forest will want to replace the forest land so that there will be additional resources for them to harvest in the future.

However, in most tropical countries, those who are extracting resources do not always have legal occupancy of the land (Palo and Lehto 1996). If a governing power cannot adequately enforce property rights, illegal squatters may take up residence in a forest area and use up all the forest's resources. In addition, the proper owner of the land is not going to reinvest in the forest if he believes that the resources will be extracted by the squatters. The squatters also have no incentive to reinvest in the forest because they have no guarantee that they will be able to continue taking resources form the forest in the future (Palo and Lehto 1996). This leads to an over-extraction of the forest's resources, and increases deforestation.

IV. Data and Empirical Estimation

The data for this paper comes from multiple sources. The majority of the data is collected from the World Bank's World Development Indicator (WDI). This forest area variable and agricultural land are measured in square kilometers. Forest area is the measurement for forestation in this model. Forestation is used as an alternative to deforestation due to the lack of available information on deforestation. GDP is measured in real US dollars with 2005 as the base year. Population is the total population of a country. Agriculture value added per worker is measured in real US dollars with 2005 as the base year. This variable is a proxy used to measure the value of agriculture productivity because it is the net output value of the agricultural sector. General government gross debt is measured as a percentage of GDP and is collected from the International Monetary Fund (IMF)'s World Economic Outlook Database. All funding data from REDD programs is collected from the voluntary REDD+ database website[1]. According to this website, the voluntary REDD+ database is a record of financing transaction between REDD partners and third party institutions. It relies on voluntary information provided by countries and institutions either giving or receiving funding.

The funding data for the REDD program is compiled from the voluntary REDD+ database. However, a portion of the data received from the database included aggregated data in which groups of countries received a lump sum of funding. Furthermore, there were institutions that received funding to disseminate it to a number of countries. Due to this reason, the funding information had to be manually constructed into 3 separate variables first: 1) Individual countries that receive direct funding through REDD. 2) Aggregated data where a number of countries receive a lump sum of funding through REDD. The assumption I had to make in extracting this information is that the lump sum of funding is divided equally between each country. 3) Funding is indirectly distributed to countries through institutions partnered with REDD. This data is unusable because the dataset does not indicate which countries are ultimately receiving the

[1] http://reddplusdatabase.org/

funding. The variable REDDFUND in the modified EKC model (equation 1) only includes the funding data by individual country and the aggregated data where groups of countries received a lump sum of funding. Since the third type of funding data was dropped, 62% (625 out of 1013 observations) of the data from the REDD funding dataset is used in this paper.

The data set being used is an unbalanced panel data set from 2006 to 2012 for a sample of 181 non-OECD countries including 36 tropical countries. The dataset is restricted to non-OECD countries because those countries that are part of the OECD are likely to be funding countries, as opposed to being recipients of the REDD funding.

The equation used in this estimation is a modified EKC model of forestation which adds REDD funding (REDDFUND) (equation 1). The subscript i signifies the i-th country, and the subscript t signifies the t-th year. All variables in the equation are in the logged form in order to develop elasticity of the dependent variable with respect to the independent variables. The one exception is the debt variable. Since the debt is already specified in a percentage point (debt as a percentage of the GDP), this variable is left as is.

Variable	**Definitions**
FOR	Forest area (square kilometers)
GDP	GDP (real dollars with 2005 as the base year)
AGLAND	Agricultural land (square kilometers)
AGVALUE	Agricultural value added per worker, a measure of agricultural productivity by value added in agriculture measures the output of the agricultural less the value of intermediate inputs (real dollars with 2005 as the base year)
POP	Total population
DEBT	General government debt (% of GDP)
REDDFUND	Usable REDD funding data in millions of dollars (real dollars with 2005 as the base year)

$$lnFOR_{it} = \beta_0 + \beta_1 lnGDP_{it} + \beta_2 (lnGDP_{it})^2 + \beta_3 lnAGLAND_{it} + \beta_4 lnAGVALUE_{it} + \beta_5 lnPOP_{it} + \beta_7 DEBT_{it} + \beta_8 lnREDDFUND_{it} + u_{it} \quad (1)$$

The logged form of GDP and the square of GDP are both included to make up the EKC model. However, since the dependent variable is measured in forestation opposed to deforestation, it is hypothesized that the sign of the coefficient for GDP will be negative, and the sign for the coefficient for the square of GDP will be positive to get the U-shaped EKC. The variable of interest is the REDD funding data. The relationship between forestation (FOR) and the REDD funding (REDDFUND) is hypothesized to be positive, indicating increased funding will lead to increased forestation through the pay-for-performance system. The other independent variables agricultural land (AGLAND), agricultural value per worker (AGVALUE), population (POP) and debt (DEBT) are all hypothesized to have a negative relationship with forestation. These relationships are taken from the literature which indicate each independent variable as being a determinate of deforestation. The literature also indicates that road coverage may play a significant role in deforestation. However, due to missing data for the majority of the countries, the road variable is left out of the equation. However, a higher GDP correlates with having better infrastructure, including a larger transportation network so the omission will not be problematic

The Hausman specification test is used to test whether the equation should be run as a fixed-effect regression, or a random-effect regression. For both fixed-effect and random-effect, the composite error term is $u_{it} = \alpha_i + \varepsilon_{it}$; where α_i is the time invariant heterogeneity, or variation across countries, and ε_{it} is the idiosyncratic error which changes both over time and across countries (Wooldridge 2012). If the Hausman test indicates that the model is a fixed-effect regression the variation between countries is unique to each country. However, if the test determines the model to be random-effect, then the variation across countries is assumed to be randomly distributed and uncorrelated with the independent variables.

Preliminary analyses indicated a multicollinearity issue with population and GDP and agricultural land (shown in appendix 1C). In order to account for the sever multicollinearity, I converted the variables into per capita form, whereas each variable is divided by the total population. The agricultural value added per worker variable is not converted, because it is already in per capita terms. The debt variable is also left as is, because it is measured as a percentage of GDP. The equation is restated in per capita terms in equation 2.

$$lnFORpc_{it} = \beta_0 + \beta_1 lnGDPpc_{it} + \beta_2(lnGDPpc_{it})^2 + \beta_3 lnAGLANDpc_{it} + \beta_4 lnAGVALUE_{it} + \beta_6 DEBT_{it} + \beta_7 lnREDDFUNpc_{it} + u_{it} \quad (2)$$

V. Results

The estimated coefficients for the restricted modified EKC model are shown in table 2. According to the Hausman specification test, it is appropriate to use the fixed-effect model for all regressions because it has been rejected. The three regressions reported in table 2 are all run without the funding variable. This creates a conventional forestation model. The coefficient estimates for countries that receive funding and those that do not receive funding are both compared to the coefficients for a model that includes all countries. This is done to see if applying the forestation model to countries that received funding differs from applying the model to countries that did not receive funding.

The purpose of this paper is to address whether agreements through the REDD program play a significant role in mitigating deforestation in tropical developing countries. In order to address this question, an unrestricted model is created by including the REDD funding in the regression. The countries of interest are those found in the tropical zone. Countries are considered tropical if they fall anywhere on the globe between the latitude of 23 degrees north and 23 degrees south (The Environmental Literacy Council).

Table 2 The Effects of Forestation per capita in a modified EKC Model – Without REDD Funding

Variables	All Countries	Countries that received funding	Countries that did not receive funding
Constant	-2.1562	-1.7677	-3.1773
	(0.8970)	(1.2535)	(1.8552)
lnGDPpc	$-.6381^{***}$	-0.5274^{**}	-0.6644
	(0.2122)	(0.2526)	(0.4995)
lnGDP2pc	0.0443^{***}	0.0380^{**}	0.0478^{*}
	(0.0130)	(0.0163)	(0.0282)
lnAGLANDpc	0.3682^{***}	0.4460^{***}	0.3217^{***}
	(0.0610)	(0.0903)	(0.0733)
lnAGVALUE	0.0631^{**}	0.0412	0.0479
	(0. 0288)	(0.0386)	(0.0383)
Debt	0 .0001	0.0001	0.0003
	(0.0001)	(0.0001)	(.0003)
Yearly dummy variables reported	Included	Included	Included
Number of countries	127	94	33
Average number of years	6.4	6.5	5.9
Number of observations	808	614	194
R^2*(within)*	0.6579	0.7035	0.6502
F-statistic	27.68^{***}	28.04^{***}	64.62^{***}

Robust Standard errors are below coefficients in parentheses

$^{***}p<0.01$;$^{**}p<0.05$;$^{*}p<0.1$

Since there is only one restriction on the model, the t-statistic is used to test for the significance of the REDD funding. When examining the countries that received funding, the p-value is insignificant, therefore I fail to reject the null hypothesis and REDD funding has no impact for all funded countries. However, when looking specifically at tropical countries, the REDD funding is shown to be significant.

The EKC holds true for both the restricted and unrestricted model, because the coefficient for the logged form of GDP is negative and the coefficient for the logged square of GDP is

Table 3 The Effects of Forestation In a modified EKC Model – With REDD Funding

Variables	Countries with funding	Tropical countries with funding
Constant	-0.3215	-2.4903
	(1.2156)	(1.040)
lnREDDFUNDpc	-0.0018	0.0029^{**}
	(0.0024)	(0.0012)
lnGDPpc	-0.8325^{***}	-0.9306^{***}
	(0.2699)	(0.2479)
lnGDP2pc	0.0607^{***}	0.0780^{***}
	(0.0188)	(0.0192)
lnAGLANDpc	0.4627^{***}	0.0734
	(0.1060)	(0.0883)
lnAGVALUE	0.0061	0.0019
	(0.0413)	(0.0408)
Debt	-0.0001	0.0001
	(0.0001)	(0.0001)
Yearly dummy variables reported	Included	Included
Number of countries	88	36
Average number of years	4.4	4.8
Number of observations	388	174
R^2 $(within)$	0.7586	0.8838
F-statistic	37.13^{***}	104.19^{***}

Robust Standard errors are below coefficients in parentheses

****p*<0.01;***p<0.05;*p<0.1*

positive. In tropical countries that received REDD funding, the regression modeling reflect that a one percent increase in GDP per capita will result in a 0.93 percent decrease in forestation per capita, and a one percent increase in GDP per capita squared will result in a 0.07 percent increase in forestation per capita. Since the dependent variable being used is forestation as opposed to deforestation, these relationships are consistent with the inverted EKC model. These relationships also coincide with Faria and Almeida (2013) who show an increase in GDP will result in an increase in deforestation, while an increase in GDP squared will result in a decrease in deforestation. The variable of interest in this model is the REDD funding data. According to the results, a one percent increase in REDD funding per capita will result in a 0.003 percent increase in forestation per capita in tropical countries that received funding. Agricultural land per capita, agricultural value added per worker and debt are all found to be insignificant in determining forestation in tropical countries receiving funding.

The fixed-effect model controls for time invariant country-specific variations which are usually unobserved. The literature shows that property rights are a country-specific factor that influences deforestation. However, since property rights are typically stagnant for a country over time, some of the county-specific heterogeneity can be observed by incorporating this variable in the forestation model. The CPIA property right index from the World Bank's website assesses the extent to which property rights and contracts are enforced within the legal system of a country. Since a country's rating has little to no variation by year, this variable could not be included directly in the regression model. Instead, the predicted forestation for countries that have high CPIA property right ratings can be compared to the expected forestation for countries that have a CPIA property right ratings. The property right CPIA index is rated on a scale from 1=low to 6=high. Dominica and Guinea are compared against one another in table 4, because Dominica has the highest consistent CPIA property right rating and Guinea has the lowest consistent CPIA property right rating out of all of the tropical countries that received funding. The predicted forestation estimates in table 4 show that while both Dominica and Guinea see an increase in forestation per capita, Dominica seems to be seeing a faster growth than Guinea. In order to get more conclusive results, similar information would have to be examined for all countries on greater timeline. However, as is, this example implies that a country that has higher property right security may see a more rapid rate of forestation per capita as compared to a country with lower property right security.

Table 4 Predicted forestation estimates for Dominica and Guinea

Year	Dominica	Guinea
	CPIA=4	CPIA=2
2006	0.0143	0.0090
2007	0.0145	0.0090
2008	0.0149	0.0090
2009	0.0149	0.0090
2010	0.0149	0.0085
2011	0.0142	0.0090
2012	0.0149	0.0085

VI. Conclusion

This paper examines how REDD funding plays a role in reducing deforestation in tropical developing countries, by creating a modified EKC model of forestation. Additionally, this paper attempts to examine how property right security plays a role in deforestation. The key findings are that REDD funding does have a significant positive relationship with deforestation in tropical counties. This shows that pay-for-performance is working despite the short number of years since REDD has been operating. The results also support previous literature on the Environmental Kuznets Curve hypothesis by reflecting the U-shaped relationship between GDP and forestation, in which an increase in GDP per capita will yield a decrease in forest land per capita and an increase in the square of GDP per capita will yield and an increase in forest land per capita. Some of the county-specific heterogeneity is observed by comparing the predicted forestation for countries with high property right security to countries with low property right security.

The results of this paper should be interpreted with caution due to an unbalanced dataset and the voluntary reporting of the REDD funding data. Ideally, this analysis would be run on a longer period to see the long-term effect of REDD funding on forestation. It would also benefit the study if the remaining 38% the funding data was reported in a way that it could be incorporated into the model. Since the REDD funding data reported is voluntary in nature, the results assume that all of the data reported is accurate. If this analysis could be run using more complete data over a longer period of time, we would be able to see the long-term effectiveness of the REDD program.

Future research should examine REDD's long-term effectiveness and address the question of moral hazard in donating to countries that experience high deforestation. If donor countries use REDD as an intermediary to distribute funding, some level of accountability should be placed on recipient countries and their performance in reducing deforestation. If recipient countries are not held to performance standards, increased incentive to allow deforestation in order to receive funding. One potential way to monitor this moral hazard is to see if there is a change in the relationship between REDD funding and forestation. If the relationship becomes negative, there is the possibility of moral hazard.

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Appendix 1A: Results for Random-Effect Models

Table A1 The Effects of Forestation per capita in a modified EKC Model – Without REDD Funding

Variables	All Countries	Countries that received funding	Countries that did not receive funding
Constant	-2.1236 (0.4885)	-1.5880 (0.5793)	-3.3771 (1.053)
lnGDPpc	$-.5996^{***}$ (0.1131)	-0.5032^{***} (0.1319)	-0.6241^{**} (0.2573)
lnGDP2pc	0.0417^{***} (0.0070)	0.0366^{***} (.0086)	0.0456^{***} (0.0145)
lnAGLANDpc	0.3953^{***} (0.0272)	0.4882^{***} (0.0366)	0.3273^{***} (0.0455)
lnAGVALUE	0.0578^{***} (0.0160)	0.0377^{**} (0.0190)	0.0476 (0.0310)
debt	0.0001^{**} (0.0001)	0.0001 (0.0001)	0.0002 (.0002)
Yearly dummy variables reported	Included	Included	Included
Number of countries	127	94	33
Average number of years	6.4	6.5	5.9
Number of observations	808	614	194
R^2*(overall)*	0.3074	0.4085	0.1646
Wald X^2	1317.08^{***}	1235.66^{***}	290.17^{***}

Standard errors are below coefficients in parentheses

$^{***}p<0.01; ^{**}p<0.05; ^{*}p<0.1$

Table A2 The Effects of Forestation In a modified EKC Model - With REDD Funding

Variables	Countries with funding	Tropical Countries with funding
Constant	-0.0956 (0.7188)	-1.9089 (0.8091)
lnREDDFUNDpc	-0.0016 (0 .0014)	0.0031^{*} (0.0018)
lnGDPpc	-0.7769^{***} (0.1638)	-0.9280^{***} (0.1647)
lnGDP2pc	0.0570^{***} (0.0111)	0.0775^{***} (0.0121)
lnAGLANDpc	0.5591^{***} (0.0463)	0.2010^{***} (0.0677)
lnAGVALUE	-0.0007 (0.0276)	0.0050 (0.0395)
debt	-0.0001 (0.0001)	0.0001 (0.0001)
Yearly dummy variables reported	Included	Included
Number of countries	88	36
Average number of years	4.4	4.8
Number of observations	388	174
R^2 (overall)	0.4568	0.4334
Wald X^2	835.76^{***}	693.37^{***}

Standard errors are below coefficients in parentheses

p<0.01;p<0.05;*p<0.1*

Appendix 1B: Predicted forestation estimates for Dominica and Guinea Equations

$$ln\widehat{FOR}pc_{it} = \beta_0 + \beta_1 lnGDPpc_{it} + \beta_2(lnGDPpc_{it})^2 + \beta_7 lnTotalfundpc_{it} \quad (3)$$

Dominica

$ln\hat{F}orestation\ 2006 = (-2.0734) + (-0.8729)\left(\ln(\frac{400000000}{70690})\right) + (0.0719)\left(ln(\frac{400000000}{70690})\right)^2 + (0.0029)(0)$= -4.248

$\hat{F}orestation\ 2006 = e^{ln\hat{F}orestation} = e^{-4.248}$ =0.0143

$ln\hat{F}orestation\ 2007 = (-2.0734) + (-0.8729)\left(\ln(\frac{420000000}{70795})\right) + (0.0719)\left(\ln(\frac{420000000}{70795})\right)^2 + (0.0029)(0)$ =-4.230

$\hat{F}orestation\ 2007 = e^{ln\hat{F}orestation} = e^{-4.230}$ =0.0145

$ln\hat{F}orestation\ 2008 = (-2.0734) + (-0.8729)\left(\ln(\frac{450000000}{70883})\right) + (0.0719)\left(ln(\frac{450000000}{70883})\right)^2 + (0.0029)(0)$ =-4.204

$\hat{F}orestation\ 2008 = e^{ln\hat{F}orestation} = e^{-4.204}$ =0.0149

$ln\hat{F}orestation\ 2009 = (-2.0734) + (-0.8729)\left(\ln(\frac{450000000}{70996})\right) + (0.0719)\left(\ln(\frac{450000000}{70996})\right)^2 + (0.0029)(0)$ = -4.205

$\hat{F}orestation\ 2009 = e^{ln\hat{F}orestation} = e^{-4.205}$ =0.0149

$ln\hat{F}orestation\ 2010 = (-2.0734) + (-0.8729)\left(\ln(\frac{450000000}{71167})\right) + (0.0719)\left(\ln(\frac{450000000}{71167})\right)^2 + (0.0029)(0)$ =-4.206

$\hat{F}orestation\ 2010 = e^{ln\hat{F}orestation} = e^{-4.206}$ =0.0149

$ln\hat{F}orestation\ 2011 = (-2.0734) + (-0.8729)\left(\ln(\frac{430000000}{71401})\right) + (0.0719)\left(\ln(\frac{430000000}{71401})\right)^2 + (0.0029)(\ln(\frac{1.42556}{71401}))$ = -4.256

$\hat{F}orestation\ 2011 = e^{ln\hat{F}orestation} = e^{-4.256}$ =0.0142

$ln\hat{F}orestation\ 2012 = (-2.0734) + (-0.8729)\left(\ln(\frac{450000000}{71684})\right) + (0.0719)\left(\ln(\frac{450000000}{71684})\right)^2 + (0.0029)(0)$ = -4.208

$\hat{F}orestation\ 2012 = e^{ln\hat{F}orestation} = e^{-4.208}$ =0.0149

Guinea

$ln\hat{F}orestation\ 2006 = (-2.0734) + (-0.8729)\left(\ln(\frac{3000000000}{9800000})\right) + (0.0719)\left(\ln(\frac{3000000000}{9800000})\right)^2 + (0.0029)(0)$ = -4.714

$\hat{F}orestation\ 2006 = e^{ln\hat{F}orestation} = e^{-4.714}$ =0.0090

$ln\hat{F}orestation\ 2007 = (-2.0734) + (-0.8729)\left(\ln(\frac{3100000000}{10000000})\right) + (0.0719)\left(\ln(\frac{3100000000}{10000000})\right)^2 + (0.0029)(0)$ =-4.714

$\hat{F}orestation\ 2007 = e^{ln\hat{F}orestation} = e^{-4.714}$ =0.0090

$ln\hat{F}orestation\ 2008 = (-2.0734) + (-0.8729)\left(\ln(\frac{3200000000}{10000000})\right) + (0.0719)\left(\ln(\frac{3200000000}{10000000})\right)^2 + (0.0029)(0)$ =-4.716

$\hat{F}orestation\ 2008 = e^{ln\hat{F}orestation} = e^{-4.716}$ =0.0090

$ln\hat{F}orestation\ 2009 = (-2.0734) + (-0.8729)\left(\ln(\frac{3200000000}{11000000})\right) + (0.0719)\left(\ln(\frac{3200000000}{11000000})\right)^2 + (0.0029)(0)$ = -4.711

$\hat{F}orestation\ 2009 = e^{ln\hat{F}orestation} = e^{-4.711}$ =0.0090

$ln\hat{F}orestation\ 2010 = (-2.0734) + (-0.8729)\left(\ln(\frac{3300000000}{11000000})\right) + (0.0719)\left(\ln(\frac{3300000000}{11000000})\right)^2 + (0.0029)(\ln(\frac{0.675}{11000000}))$ = -4.761

$\hat{F}orestation\ 2010 = e^{ln\hat{F}orestation} = e^{-4.761}$ =0.0085

$ln\hat{F}orestation\ 2011 = (-2.0734) + (-0.8729)\left(\ln(\frac{3400000000}{11000000})\right) + (0.0719)\left(\ln(\frac{3400000000}{11000000})\right)^2 + (0.0029)(0)$ = -4.715

$\hat{F}orestation\ 2011 = e^{ln\hat{F}orestation} = e^{-4.715}$ =0.0089

$ln\hat{F}orestation\ 2012 = (-2.0734) + (-0.8729)\left(\ln(\frac{3500000000}{11000000})\right) + (0.0719)\left(\ln(\frac{3500000000}{11000000})\right)^2 + (0.0029)(\ln(\frac{0.798591}{11000000}))$= -4.764

$\hat{F}orestation\ 2012 = e^{ln\hat{F}orestation} = e^{-4.764}$ =0.0085

Appendix 1C Pair-wise correlations

Table C1 Pair-wise correlation of severe multicollinearity (non-logged form)

	FOR	AGLAND	AGVALUE	GDP	POP	REDDFUND	DEBT
FOR	1						
AGLAND	0.581	1					
	0						
AGVALUE	-0.0486	-0.0787	1				
	0.1477	0.0188					
GDP	0.4885	0.8559	-0.0271	1			
	0	0	0.4215				
POP	0.2981	0.7274	-0.0885	0.8533	1		
	0	0	0.0082	0			
REDDFUND	0.3099	0.2798	-0.0167	0.2903	0.1148	1	
	0	0	0.6704	0	0.0014		
DEBT	-0.055	-0.0928	-0.0342	-0.0469	-0.0065	-0.0315	1
	0.0791	0.003	0.3299	0.1388	0.8348	0.3947	

Table C2 Pair-wise correlation of severe multicollinearity (logged form)

	lnFOR	lnAGLAND	lnAGVALUE	lnGDP	lnPOP	lnREDDFUND	lnGDP2	DEBT
lnFOR	1							
lnAGLAND	0.6109	1						
	0							
lnAGVALUE	-0.3167	-0.3728	1					
	0	0						
lnGDP	0.2793	0.5996	0.182	1				
	0	0	0					
lnPOP	0.5392	0.8863	-0.3076	0.7868	1			
	0	0	0	0				
lnREDDFUND	0.3135	0.2104	-0.0861	0.1983	0.2537	1		
	0	0	0.0276	0	0			
lnGDP2	0.2768	0.5924	0.1866	0.998	0.7817	0.194	1	
	0	0	0	0	0	0		
DEBT	-0.0769	-0.2153	-0.0992	-0.2877	-0.1838	-0.1744	-0.2787	1
	0.014	0	0.0046	0	0	0	0	

Appendix 1D: Countries Observed

- Afghanistan
- Albania#
- Algeria#
- American Samoa
- Andorra*
- Angola#
- Antigua and Barbuda#
- Argentina#
- Armenia#
- Aruba
- Azerbaijan#*
- Bahamas, The#*
- Bahrain
- Bangladesh#*
- Barbados#
- Belarus
- Belize#*
- Benin#
- Bermuda*
- Bhutan#*
- Bolivia#
- Bosnia and Herzegovina*
- Botswana#*
- Brazil#*
- Brunei Darussalam*
- Bulgaria#
- Burkina Faso#*
- Burundi#*
- Cabo Verde#*
- Cambodia#*
- Cameroon#*
- Cayman Islands*
- Central African Republic#*
- Chad#*
- Channel Islands*
- China#*
- Colombia*
- Comoros
- Congo, Dem. Rep.*
- Congo, Rep.#*
- Costa Rica#*
- Cote d'Ivoire#
- Croatia*
- Cuba#*
- Curacao
- Cyprus
- Djibouti*
- Dominica#*
- Dominican Republic#*
- Ecuador*
- Egypt, Arab Rep.*
- El Salvador#*
- Equatorial Guinea#*
- Eritrea
- Ethiopia#*
- Faeroe Islands*
- Fiji#
- French Polynesia
- Gabon#*
- Gambia, The#
- Georgia#
- Ghana#*
- Greenland
- Grenada#
- Guam
- Guatemala#
- Guinea#*
- Guinea-Bissau#
- Guyana#
- Haiti#*
- Honduras
- Hong Kong SAR, China
- India*
- Indonesia#*
- Iran, Islamic Rep.#*
- Iraq
- Isle of Man*
- Jamaica#
- Jordan*
- Kazakhstan*
- Kenya#*
- Kiribati
- Korea, Dem. Rep.#
- Kosovo
- Kuwait
- Kyrgyz Republic#
- Lao PDR*
- Latvia*
- Lebanon
- Lesotho
- Liberia#*
- Libya*
- Liechtenstein*
- Lithuania
- China
- Macedonia, FYR*
- Madagascar#
- Malawi#*
- Malaysia#*
- Maldives*
- Mali#
- Malta*
- Marshall Islands
- Mauritania#*
- Mauritius*
- Mexico#
- Micronesia, Fed. Sts.*
- Moldova*
- Monaco
- Mongolia#*
- Montenegro
- Morocco#
- Mozambique#
- Myanmar#*
- Namibia#*
- Nepal#*
- New Caledonia*
- Nicaragua#
- Niger#
- Nigeria#
- Northern Mariana Islands*
- Oman*
- Pakistan#
- Palau*
- Panama#
- Papua New Guinea#
- Paraguay#
- Peru#
- Philippines#
- Puerto Rico*
- Qatar
- Romania
- Russian Federation#
- Rwanda#*
- Samoa#*
- San Marino
- Sao Tome and Principe#
- Saudi Arabia*
- Senegal#
- Serbia
- Seychelles
- Sierra Leone#
- Singapore#
- St Marten
- Solomon Islands#
- Somalia
- South Africa#
- South Sudan
- Sri Lanka#
- St. Kitts and Nevis#
- St. Lucia#
- St. Martin (French part)
- St. Vincent and the Grenadines#
- Sudan#
- Suriname#
- Swaziland#
- Syrian Arab Republic#
- Tajikistan
- Tanzania#
- Thailand#
- Timor-Leste#
- Togo#
- Tonga
- Trinidad and Tobago#
- Tunisia#
- Turkmenistan
- Turks and Caicos Islands
- Tuvalu
- Uganda#
- Ukraine
- United Arab Emirates
- Uruguay
- Uzbekistan
- Vanuatu#
- Venezuela, RB#
- Vietnam#
- Virgin Islands (U.S.)
- West Bank and Gaza
- Yemen, Rep.
- Zambia#
- Zimbabwe#

#=Country Received REDD Funding, *=Tropical Country