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Development and application of a new Forestation Index: global forestation patterns and drivers

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Development and application of a new Forestation Index: global forestation patterns and drivers

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Abstract

Deforestation has long been heavily studied; several proximate and underlying causes behind the global decrease of forest extent have been discussed. However, systematic analyses of positive examples are sparse, even if forestation is happening in almost 70 countries (on approximately 40% of the world forested area). This study focuses on countries where forest cover increased between 1990 and 2010. As "forests" is a heterogeneous group, a biodiversity-corrected Forestation Index is also introduced to distinguish between different forms of "environmentally valuable" new forests (that are expected to have positive impact on biodiversity) and monocultures (that are debatable with that respect). OLS regression is used to reveal factors that may influence the observed patterns. Our results present some evidence to support the existence of an environmental Kuznets curve (EKC). Direct conservation investments appear to have negative effect on forestation which implies substitution of measures. Several traditional factors, which are important in deforestation (such as corruption, economic freedom, etc.) seems to have no impact from forestation perspective. Results show that refinement is needed during the modelling of forestation and different types should be acknowledged – treatment of forests as a homogenous category is an oversimplification.

Keywords: Forests, biodiversity, global model, environmental Kuznets curve, environmental policy

JEL classification: Q23, Q56, Q57

Egy új erdősítési index kifejlesztése és alkalmazása: globális erdősítési mintázatok és hajtóerők

Benedek Zsófia – Fertő Imre

Összefoglaló

Az erdőirtásokat régóta alaposan tanulmányozzák: az erdők kiterjedésének globális csökkenése hátterében számtalan közvetlen és közvetett hajtóerő szerepét vitatja a szakirodalom. A pozitív példák szisztematikus elemzése azonban nem jellemző annak ellenére, hogy mintegy 70 országban (az összes erdőterület mintegy 40%-án) erdősülési folyamatok zajlanak. Jelen tanulmány azokra az országokra fókuszál, amelyek esetében nőtt az erdőborítás 1990 és 2010 között. Mivel az „erdő" kifejezés egy igen heterogén csoportot takar, kifejlesztettünk egy biodiverzitással korrigált erdősítési indexet, amely képes különbséget tenni a „környezeti szempontból értékes" (vagyis a biodiverzitásra pozitívan ható) új erdők és monokultúrák között (ez utóbbiak biodiverzitásra gyakorolt hatása vitatott). OLS-regressziót használtunk annak érdekében, hogy feltárjuk a megfigyelt mintázatok mögött húzódó lehetséges hajtóerőket. Eredményeink arra utalnak, hogy az erdőirtás és az erdősítés összefüggésében értelmezhető a környezeti Kuznets-görbe. A természetvédelmi intézkedések negatívan hatnak az erdősítési folyamatokra, ami felveti a tevékenységek (természetvédelem vs. erdősítés) helyettesítésének kérdését. Számos, az erdőirtások során meghatározó tényező (pl. korrupció, gazdasági szabadság) nem hozható összefüggésbe az erdősítéssel. Összességében megállapítható, hogy az eltérő erdőtípusok elkülönítése alapvető az erdősítési folyamatok vizsgálata során, mert az erdők homogén csoportként történő kezelése a valóság túlzott mértékű leegyszerűsítése.

Tárgyszavak: erdő, biodiverzitás, globális modell, környezeti Kuznets-görbe, környezetpolitika

JEL kód: Q23, Q56, Q57

1. INTRODUCTION

Among terrestrial ecosystems, forests are thought to be responsible for ensuring the most diverse ecosystem services (including provision of raw materials, climate regulation, water treatment, etc.); forests are of vital importance in terms of biodiversity maintenance, too. This is the reason why ongoing global deforestation is regarded as a crucial environmental issue. Defining factors that may cause forest loss and recognizing their relationship is of great interest to domestic and international policymakers (Meyer et al., 2003). Geist and Lambin (2002) assess proximate causes (immediate human actions at the local level) and underlying driving forces (that are fundamental economic and social processes, such as market growth, demographic factors, agricultural policies, property right issues, public attitude, etc.). In their meta-analysis they conclude that underlying factors are interrelated and act in various combinations.

While understanding of deforestation drivers is becoming more and more solid, knowledge on forestation at the global scale is remarkably underdeveloped; although learning from positive examples would be similarly useful. The existing literature focuses mostly on case studies (e.g. Elmqvist et al., 2007; Nagendra, 2007); scholar attention seems to slowly move towards broad-scale patterns and drivers (see Nagendra and Southworth, 2010; Rudel et al., 2005). Our study contributes to the general understanding by focusing on countries where the forest cover increased between 1990 and 2010, with the aim of analysing the possible effects of certain economic, institutional and social drivers.

2. MATERIALS AND METHODS

2.1. FORESTATION CHANGES

Forest cover data were derived from FAO Global Forest Resources Assessment (FAO, 2010). In the database information is available for most countries and is regularly collected at the national level. FAO FRA data are heavily criticized as countries use differing frequencies, classification systems and assessment methods when monitoring their forests, making it difficult to obtain consistent data – and track regional and global trends (Grainger, 2008). To answer the criticism, FAO foresters constantly improve the framework (data collection, processing, validation, compilation and analysis) and previous forest extents are constantly recalculated in the newer reports, which makes data from different periods comparable. Regarding this and the fact that only FAO provides national level estimates; and that economic and institutional drivers of forest extent change vary greatly between countries, the FAO database is indeed the best available source for our analysis.

Based on the data for the years 1990 and 2010 we calculated the change for each country (and territory):

$$CHANGE_i = \frac{COVER_{i,2010}}{COVER_{i,1990}} \qquad (1)$$

where $CHANGE_i$ is the change in forestation between 1990 and 2010 in country i, i=1,...n countries; $COVER_i$ is the forest coverage in country i (expressed in 1000 ha). In our study we focused on countries (territories) where the change was positive.

2.2. FORESTATION INDEX

Forests are defined as landscapes exceeding 0.5 hectare with trees higher than 5 meters and a canopy cover of more than 10 percent (FAO, 2010). A wide range of ecosystems are involved in this definition, from primeval forests to monoculture plantations of introduced tree species. Natural forests that are closer to the original state support more diverse forms of life, which result in the production of more diverse and more stable ecosystem services. Therefore, the biodiversity (differences) are of major importance not only for conservationists but from well-being and policy perspectives, too (Kumar, 2010; MEA, 2005). Halting biodiversity loss is one of the greatest challenges today (Rockström et al., 2009), to which different forest types contribute to different extent. In order to distinguish between the types and regard also their expected effect on biodiversity, we introduce a biodiversity corrected Forestation Index.

In the FAO database three major forest categories exist: primary forests (of native species where there are no signs of human intervention), naturally regenerated forests (where selective logging is predominate) and planted forests (where clear-cutting, planting and/or deliberate seeding is typical). For the latter two, countries report also on the ratio of forests composed of native and introduced species, respectively. Empirical evidence shows that overall biodiversity is clearly affected by management type; maintenance of diverse habitats and structural heterogeneity is crucial for biodiversity conservation (Hansen et al., 1991), and clear-cut forests in which the composition of tree species altered have the strongest effect (Paillet et al., 2010). Taking that structural diversity (which is the indicator of habitat complexity) is a key factor in supporting the overall biodiversity; we assume that four major forest types can be identified:

- primary forests,
- naturally regenerated forest (with or without introduced species). Compared to the structural diversity of primary forest (100%) we assume that structural diversity (habitat complexity) of naturally regenerated forests is around 80%.
- Planted forests of native species (where clear-cutting and planting and/or deliberate seeding is typical). Compared to primary forests, the structural diversity is assumed to be 50%.
- Planted forests of introduced species (monocultures). Compared to primary forests, the structural diversity is assumed to be 10%.

The next step is to assess the differences of the major forest types in terms of overall biodiversity. We apply the species number, which is a widely used indicator for biodiversity (Claridge et al., 1997). Species-area relationship (MacArthur and Wilson, 1967) is often used for making biodiversity predictions for a given area (Werner and Buszko, 2005):

$$S = cA^z, \qquad (2)$$

in linear form:

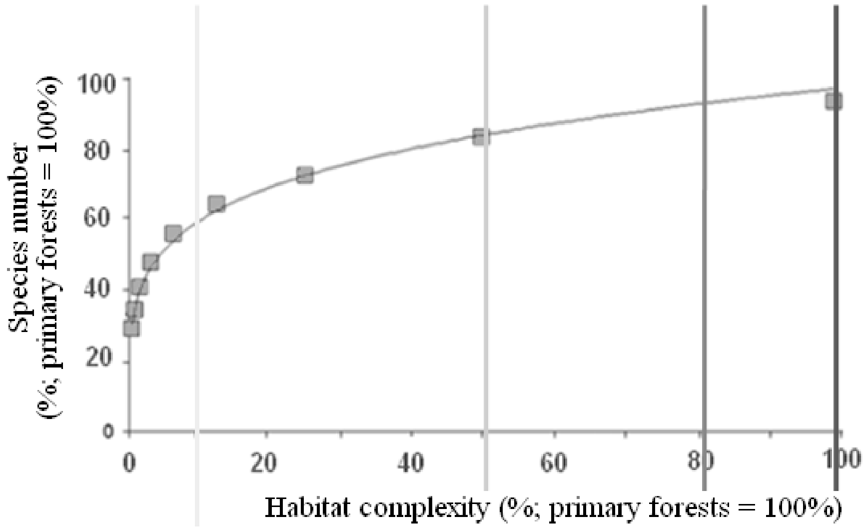
$$\log S = \log c + z \log A, \qquad (3)$$

where S is the number of species, A is the area, and c and z are constants; the latter serves as the slope of the species area relationship in case of log-log specification. Larger areas systematically tend to have more species. Species-area relationship is one of the general rules of ecology, which is empirically verified in many cases. The literature suggests that effect of area is interrelated with the effect of habitat diversity (Kallimanis et al., 2008; Marini et al., 2010; Storch et al., 2003) as larger areas have more habitats that may be used by additional taxa. If the area (or habitat complexity) is expressed as the percentage of the highest possible value (which is the habitat complexity of primary forests in our case), then the resulting species number is also given as percentage (Fig 1), which we denote as the Biodiversity Factor (BF_j) of forest type j.

Figure 1.

Relationship of habitat complexity and species numbers

The estimated habitat complexity values are presented as vertical lines



The shape of the curve depends on the species (size, mobility), ecosystem type, isolation, etc., but there are some general findings, especially about z value, which is typically ranges from 0.15 to 0.35 and is higher for isolated areas such as islands (Lomolino, 1989). Functions are reported for several forest taxa (e.g. Báldi and Kisbenedek, 1999; Browne and Peck, 1996; Marini et al., 2010; Tews et al., 2004). We calculated BFj-s in these individual cases and generated their average. This way we modelled the species-area(habitat diversity) curve for a "general species". The use of the hypothetical response of a simulated "virtual species" is often used in large-scale modelling, e.g. when the potential effect of climate change on vegetation is analysed (Bonan et al., 2003; Foley et al., 1996; Hirzel et al., 2001). Biodiversity Factors of primary forests, naturally regenerated forests, planted forests with native species, planted forests with introduced species are 1.00; 0.95; 0.8; 0.6, respectively.

We propose a Forestation Index that takes the "conservation value" (differences in overall biodiversity) of the forest types into account:

$$FI_i = \frac{PRIM_i \times BF_{PRIM} + NATR_i \times BF_{NATR} + PLTD_i \times BF_{PLTD \times NATIVE} \times NATIVE_{PLTD_i} + PLTD_i \times BF_{PLTD \times INTR} \times INTR_{PLTD_i}}{GROWTH_i}, \quad (4)$$

where FIi is the Forestation Index of country i, i=1,...n countries. PRIMi is the extent of primary forests is country i, BFPRIM is the Biodiversity Factor of primary forests. NATRi is the extent of naturally regenerated forests is country i, BFNATR is the Biodiversity Factor of naturally regenerated forests. PLTDi is the extent of planted forests is country i, BFPLTD×NATIVE is the Biodiversity Factor of planted forests of native species. NATIVEPLTDi is the ratio of native species in planted forests of country i. The FAO database contains information only on the ratio of introduced species in planted forests (INTRPLTDi); thus

$$NATIVE_{PLTD_i} = 100 - INTR_{PLTD_i}. \tag{5}$$

BFPLTD×INTR is the Biodiversity Factor of planted forests of introduced species. The index is constructed to acknowledge all effort made in forestation (as all forests provide certain benefits to societies, e.g. carbon sequestration), but higher score is attributed to forest types that are more natural as the scope of ecosystem services is more comprehensive.

2.3. POSSIBLE FACTORS INFLUENCING FORESTATION

Forestation activities may base on different drivers. One obvious candidate is the level of economic development. However, North (1990) emphasize that because of imperfect insight and incomplete information, institutions are intended to reduce the uncertainty in exchange, and play a crucial role in a society by influencing the enforceability of contracts and reducing transaction costs. The literature argues that institutions can provide positive externalities for private transactions, and consequently reduce transaction costs and thus play an important role in influencing the overall level of economic performance. In sum, beyond the traditional explanatory variables we focused on institutional factors to analyse changes in forestation.

The deforestation literature proposes several factors that may act as underlying drivers in case of increasing forestation, too. Our search for the possible factors was based on the work of Meyer and colleagues (2003) who distinguish diverse economic, institutional, social capital and other variables. Table 1 displays the variables we finally appled in our models, their description, units of measurement and their expected relationship with the changes in forest cover.

Table 1.

Possible explanatory variables and expected relationship with forest cover change

Variable	Description	Unit	Expected sign
Economic			
Economic development	per capita GDP, per capita GDP^2	constant 2000 US$	+-
Trade in forestry	Value of export - value of import	US$ (1990)	+-
Institutional			
Economic Freedom	Index of Economic Freedom (1-100)	Index	+
Other factors			
Arable land	% of land area	%	-
Coverage of protected areas	% of land area	%	+
Instruments			
Population density Population density ^{2}	people per sq. km of land area		
Age dependency ratio Age dependency ratio^2	Ratio of dependents (people aged <15 or >64) to the working-age population (15-64)	%	

The effect of Economic development (measured with the per capita GDP) on forestation is questionable. There is evidence for the existence of the inverse U-shaped environmental Kuznets curve (EKC) in the deforestation literature (Bhattarai and Hammig, 2001; Culas, 2007; Ehrhardt-Martinez et al., 2002); however, it is debated by others (e.g. Koop and Tole, 1999; Meyer et al., 2003; Mills and Waite, 2009). Trade in forestry captures how much a country relies on the export of their forestry products. The expected effect may vary as some (poorer) countries may exploit their resources, but dependence on forestry product export may also result in more investments in the strengthening of the export basis.

Economic freedom, in general is expected to have positive effect on forestation as freedom, economic and legal stability allows investments that typically return in the long run. Index of Economic Freedom (of The Heritage Foundation and Wall Street Journal) is a composite indicator of Property rights; Freedom from corruption; Fiscal freedom; Government spending; Business freedom; Labour freedom; Monetary freedom; Trade freedom; Investment freedom; Financial freedom. The summary indicator was included in the models.

Arable land is expected to have negative effect on forestation as agriculture is documented to be one of the major drivers in deforestation (Geist and Lambin, 2002). Coverage of protected areas is one of the indicators to measure the advances towards the targets of the Convention on Biological Diversity (BIP, 2010). It is used to reflect the commitment and effort made by the government (and also the effective environmental awareness of the society). It is expected to affect forestation positively.

Instruments are briefly discussed in chapter 2.4.

Data are from institutional databases: The World Bank (WB, 2012) (Economic development, Arable land, Age dependency ratio, Population density). Export and import data are from the FAO (2012). The Index of Economic Freedom data are from the database of The Heritage Foundation (HF, 2012), while data on the Protected area coverage are from the World Database on Protected Areas (UNEP-WCMC and IUCN, 2011). As forests are terrestrial ecosystems, data on terrestrial protected areas were used in our analysis.

All the data refer to the year 1990 as this is the starting point of the changes in forestation that we focus on. This way the cross section reveals the set of factors that may contribute to the increase in forest cover. The only exception is the Corruption Perception Index, which is for 2010. The reason behind is that the method was developed after 1990 and data are available for most of the countries only from the third part of the 2000's. Missing data were estimated by means of linear interpolation.

2.4. THE REGRESSION MODELS

There is no agreement in empirical EKC literature on appropriate methodology. In particular, calculations give rise to a variety of concerns in terms of the selection and number of countries examined and the choice on additional variables included. The first issue is the functional form of the relationship between environmental degradation and economic development. Although Dietz and Adger (2003) consider three hypothetical relationships including linear, parabolic and hyperbolic, empirical research focus on the inverted U shape functional form. The second issue relates to econometric methodology, which also depends on the employed dataset (cross sectional/panel) resulting a wide variety of approaches from parametric to non parametric solutions.

Having cross-sectional data we considered two model specifications. First, we applied the following ordinary least squares method (Model 1):

$$CHANGE_i = \beta_0 + \sum_{i=1}^{n}\sum_{k=1}^{K}\beta_k X_{i,k} + u_i, \qquad (6)$$

where CHANGEi is the change in the forest cover between 1990 and 2010 in country i, i=1,...n countries. β0 is the intercept, βk are the estimated coefficients, Xk (k=1,...K) are the explanatory variables presented in Table 1, u represents the error term. Similarly, another model was estimated, where Forestation Index was used as the dependent variable (Model 2):

$$FI_i = \beta_0 + \sum_{i=1}^{n}\sum_{k=1}^{K}\beta_k X_{i,k} + u_i. \quad (7)$$

Recently Lin and Liscow (2013) have raised different forms of possible endogeneity issues with respect to the EKC. First, there is a simultaneity bias due to the possible reverse causality between economic development and environmental degradation. The second endogeneity problem comes from the omitted variable bias. In order to deal with endogeneity issues we employed instrumental variable approach. Instruments were age dependency ratio, population density, age dependency ratio squared, population density squared.

3. EMPIRICAL RESULTS AND DISCUSSION

There are 67 countries and territories where forest cover has increased between 1990 and 2010 (Table 2). These areas had the 38.2% of world forests in 1990 and 41.7% in 2010. This increase is partly due to the positive changes in the countries and partly to the forest loss in the rest of the world. Cook Island and Réunion were excluded from further analysis as data of most explanatory variables were not available for them.

Table 2.

List of countries/territories where forest cover increased between 1990 and 2010

Country/territory	Change	FI	Country/territory	Change	FI
Belarus	0.109	0.890	Lithuania	0.111	0.874
Belgium **	0.001	15.95	Luxembourg	0.012	0.950
Bhutan	0.071	0.948	Macedonia. FYR	0.094	0.950
Bulgaria	0.180	1.023	Moldova	0.210	0.947
Cape Verde	0.466	0.600	Morocco	0.016	0.573
Chile	0.063	0.695	Netherlands	0.058	0.750
China	0.316	0.804	Norway	0.102	0.873
Cook Islands*	0.067	0.950	Philippines	0.167	0.934
Costa Rica	0.016	1.371	Poland	0.051	0.828
Côte d'Ivoire	0.018	0.640	Puerto Rico	0.923	0.950
Croatia	0.038	1.022	Réunion*	0.011	0.950
Cuba	0.395	0.915	Romania	0.032	0.906
Cyprus	0.075	0.857	Russia	0.000	1.570
Czech Republic	0.011	0.768	Rwanda	0.368	0.622
Denmark	0.222	0.765	Serbia	0.173	0.878
Egypt	0.591	0.634	Slovakia	0.006	0.964

Country/territory	Change	FI	Country/territory	Change	FI
Fiji	0.064	0.429	Slovenia	0.055	0.992
Finland	0.012	0.104	Spain	0.315	0.917
France	0.097	0.935	St Lucia	0.068	0.983
Gambia	0.086	0.950	Swaziland	0.193	1.025
Germany	0.031	0.870	Sweden	0.034	0.691
Greece	0.183	0.943	Switzerland	0.077	0.928
Hungary	0.127	0.788	Syria	0.320	0.766
Iceland	2.333	0.644	Tajikistan	0.005	0.792
India	0.070	0.774	Tunisia	0.565	0.720
Iraq	0.026	0.950	Turkey	0.171	0.804
Ireland	0.589	0.648	Ukraine	0.046	0.851
Israel	0.167	0.740	United Arab Emirates	0.294	0.800
Italy	0.205	0.941	United Kingdom	0.103	0.688
Japan	0.001	2.315	USA	0.026	0.836
Kuwait	1.000	0.771	Uruguay	0.896	0.621
Kyrgyzstan	0.141	0.947	Uzbekistan	0.076	0.618
Latvia	0.057	1.029	Vietnam	0.474	0.821
Lesotho	0.100	0.600			

*Cook Island and Réunion were excluded from further analysis due to the lack of data.
** Belgium was excluded from Model 2 (the FI-estimation) as its FI-value exceeded the rest by an order of magnitude.

Descriptive statistics are displayed in Table 3.

Table 3.

Descriptive statistics of the variables used in the analyses

Variable	Obs	Mean	Std. Dev.	Min	Max
GDP	67	9100.572	10466.99	-835.4459	36597.67
GDP^2	67	1.91e+08	3.25e+08	51750.73	1.34e+09
Trade in forestry	65	-529857.7	2659951	-1.16e+07	8790627
Economic Freedom	66	52.26818	25.4333	-64.5	87
Protected area coverage	67	7.208491	6.562596	.0511623	31.93464
Arable land	67	21.73699	15.9221	.0698254	60.41519

The final results are shown in Table 4a (on the outcomes of Model 1, where forest cover change was applied as the dependent variable) and in Table 4b (for Model 2, Forestation Index).

The first regression is the OLS with heteroscedastic robust standard errors. The second and third regressions are instrumental variables (IV) regressions. In both IV regressions

GDP and GDP2 are instrumented with age dependency ratio, population density, age dependency ratio squared, population density squared.

Due to the rejection of Breusch-Pagan/Cook-Weisberg test for heteroskedasticity, standard errors had to be adjusted, so we employed heteroscedastic robust standard errors with OLS. With IV GMM, we applied a robust weighting matrix that is optimal in case of heteroskedastic error term. Kleibergen-Paap underidentification LM test examines whether instruments are adequate to identify the equation. We also conducted a Hansen overidentification test (null hypothesis: the instruments are uncorrelated with the error term). Results show that the instruments are appropriate. Based on Lin and Liscow (2013) we used a Wu-Hausman test to test for the endogeneity of income, i.e. whether the addition of the residual (that is derived from a regression of GDP on all the exogenous variables) to the original model has a significant coefficient (null hypothesis: GDP is exogenous). According to the results, income is endogenous for the regressions of change in forest cover.

Table 4a.

Regression results of Model 1 (Change)

Dependent variable	**Change**		
	OLS	IV GMM	COND IV
GDP	0.00002247*	0.00005432**	0.00005888*
GDP^2	-5.832e-10*	-2.021e-09**	-2.192e-09*
Trade in forestry	-1.601e-08	-2.990e-08**	-3.142e-08**
Economic Freedom	-0.00042634	0.00033087	0.00020116
Protected area coverage	-0.01457651***	-0.016023***	-0.0159831***
Arable land	-0.00620104*	-0.007550***	-0.00910244**
Intercept	0.36316314***	0.333571***	0.37463978***
Number of observations	65	65	65
R^2	0.1626		
Breusch-Pagan / Cook-Weisberg test for heteroskedasticity (p value)	0.0000		
Underidentification test (Kleibergen-Paap rk LM statistic) (p value)		0.1165	0.1165
Hansen J statistic (overidentification test of all instruments) (p value)		0.5458	0.5990
Wu-Hausman F-test of endogeneity of GDP (p value)		0.0462	0.0535
Significance levels: *: 0.01; **: 0.05; ***: 0.001.			

Per capita GDP and GDP2 prove to be significant under all specifications (though the levels of significance vary). Different signs (positive GDP and negative GDP2) indicate the presence of environmental Kuznets relation. When endogeneity issue is addressed, the variable of Trade is significant at the 5% level and bears negative sign, which means that increased export and/or decreased import goes together with less increase in forest cover.

This suggests that investments in forest regeneration are less typical at the global level, even if "conscious" countries are concerned. The variable of Arable lands confirms our expectations and it is significant at the 1 and 5% levels, when endogeneity is also concerned. Protected area coverage (which is significant at 1% level under all specifications) is of an unexpected sign. More extended protected areas in a country predict lower level of forestation, thus conservation measures as such seems to be substitutes for investments in forestry. This result draws the attention on the dominance of reserve perspective, despite the fact that scholars have long been emphasising the importance of matrix habitats (Franklin, 1993; Henderson et al., 1985; Jules and Shahani, 2003) and conservation benefits of sustainably managed industrial forests – even plantations (Bhagwat et al., 2008; Brockerhoff et al., 2008; Fischer et al., 2006). However, changes in perspectives and environmental effect are expected only in the long run.

Implementation of the regressions of in case of Model 2 was the same. The only difference between the model layouts is that Belgium was excluded from Model 2 as its FI-value exceeded the rest by an order of magnitude.

Table 4b.

Regression results of Model 2 (FI)

Dependent variable		**FI**	
	OLS	IV GMM	COND IV
GDP	-0.0000256**	-0.00006722*	-0.00008341*
GDP^2	8.525e-10**	2.669e-09*	3.172e-09*
Trade in forestry	-4.485e-08*	-2.861e-08*	-2.433e-08
Economic Freedom	-0.00007207	-0.00044715	0-.0002093
Protected area coverage	0.00354522	0.00410793	0.00645568
Arable land	0.00122994	0.0036192	0.0050278
Intercept	0.85604847***	0.85978141***	.84656396***
Number of observations	64	64	64
R^2	0.3449		
Breusch-Pagan / Cook-Weisberg test for heteroskedasticity (p value)	0.0000		
Underidentification test (Kleibergen-Paap rk LM statistic) (p value)		0.1183	0.1183
Hansen J statistic (overidentification test of all instruments) (p value)		0.7247	0.7411
Endogeneity test of endogenous regressors (p value)		0.0242	0.0252

Significance levels: *: 0.01; **: 0.05; ***: 0.001.

The effect of the analyzed variables is less clear in Model 2, when one distinguishes between different forest types based on their biodiversity-related values. When endogeneity is concerned, the effect of economic development and trade becomes significant only at the

10% level. Interestingly, the signs of GDP and GDP2 are reversed. The rest of the variables apparently have no effect. These differences between the models suggest that treating forest types in a similar way may be an oversimplification and results must be treated with caution. Fine elaboration is needed, and understanding the impact of potential drivers requires further research.

4. CONCLUSIONS

This paper establishes a new approach in global deforestation literature as it focuses on positive examples, where forest cover increased between 1990 and 2010. We would like to draw attention to the fact that besides studying underlying patterns and drivers of deforestation, positive examples also should be analyzed as the role of new sets of variables can be realized and understood this way. As in all global-scale studies, the results cannot be used to evaluate any specific country; but the aim is contribute to the understanding of general role of several economic, institutional and social factors involved in (de)forestation. Such understanding may help in the development of international agreements to drive national environmental policies.

Analysis of forestation is more challenging, compared to the examination of deforestation, as there are diverse forms of forests from primary forests of highest conservation value to forest plantations of introduced species. We introduced a Forestation index that takes the differences related to overall biodiversity (as a potential to produce more diverse and stable ecosystem services) into account. This Index (more precisely, the Biodiversity Factors) in the current form is a first attempt to analyze the possible factors that may have influence on forestation. Results show that such refinement is definitely needed to acknowledge the heterogeneity of forests.

A minor disadvantage of our Index is that it may imply that conversion between forest types is possible, but it is always the case where areas are concerned in an environmental indicator (see the discussion of Mózner et al., 2012 on Ecological Footprint). In case of deforestation, the exchange of a smaller primary forest for a larger planted one with introduced species would definitely cause a global biodiversity loss and an irreversible damage. In case of forestation however, (if it happens on abandoned agricultural lands, without the conversion environmentally valuable habitats), the changeability issue emerges only as a potential opportunity cost not having as environmentally valuable forest in the future that would be otherwise possible (but there are other benefits, like more ecosystem services of other kind). Calculation of this opportunity cost would require the listing and valuation of all ecosystem services, which is practically impossible to implement. To summarize, our opinion is that the changeability issue does not limit the applicability of our Forestation Index.

Finally, increase in forest cover as such (even if the extent of primary forests is increased) does not necessarily mean that provision of ecosystem services is increased or biodiversity loss has been halted or reversed (Hall et al., 2012). Forest extent may increase due to the loss of other habitats and their associated biodiversity, so trends should be considered with caution.

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