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Laura Recuero Virto - Denis Couvet

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Economic growth determinants in countries with blue carbon: Natural capital as a limiting factor?[1]

Laura Recuero Virto
National Museum of Natural History &
Regulatory Authority of Railway and Road Activities
laura.recuero-virto@arafer.fr

&

Denis Couvet
National Museum of Natural History
denis.couvet@mnhn.fr

Abstract

In this paper, we explore the determinants of economic growth in countries with blue carbon, i.e. countries with open access to the sea and high mangrove mitigation potential, to explore the effects of potential anthropogenic pressures on these coastal ecosystems. For this purpose, we build a data set with 23 countries with blue carbon across different regions in the world for the period 1960-2009. We estimate the augmented Solow model including new growth theories, under a Bayesian moving average methodology that accounts for uncertainty. We find evidence that the neoclassical theory (the initial income and the investment in physical capital variables) as well as the demography, the macroeconomic policy and the natural capital theories are the robust determinants of economic growth in countries with blue carbon. In contrast, the investment in physical capital variable, and the macroeconomic policy and the natural capital theories are not relevant when using a worldwide sample of countries. Our contribution is twofold. Firstly, natural capital exploitation, together with the high fertility rates in countries with blue carbon, highlight the potential anthropogenic pressures that coastal areas with blue carbon can be subject to such as land conversion for agriculture or aquaculture, farming run-offs, over-exploitation of blue carbon resources, urbanization, uncontrolled sewage and public works which, in turn, can degrade blue carbon ecosystems. Given these findings, we highlight the role of central governments to provide incentives for the protection of these nature-based solutions at the level of local policy makers and communities, and of international financial institutions to provide financial support for such initiatives in the developing countries that are represented in our data set. Secondly, our results on the role of natural capital on economic growth is largely consistent with the findings in the empirical literature on the economic growth determinants in developing countries. Indeed, compared to an average country the value of national natural capital per capita is reduced by more than half and there is evidence in the empirical literature that this is limiting factor for economic growth. In addition, there is also empirical evidence that a too strong economic dependence on national natural capital, almost two times higher than in an average country in our case, has a negative impact on economic growth.

JEL-codes: O10, O13, Q20, Q22

Key-words: Economic growth, blue carbon conservation

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1. Motivation

Oceans and coasts represent the largest carbon sink on Earth, removing approximately 2 Gton CO2 per year, about 25% of anthropogenic emissions (Duarte, 2014). They remove over half of all the biological carbon captured in the world (Nellemman *et al.,* 2009). In relative terms, once deforestation is taken into account, the net land carbon uptake is smaller than that of oceans and coasts. Amongst ocean and coastal carbon sinks, the latter (i.e. mangroves, seagrass meadows, tidal marshes and macroalgae) supports intense carbon burial rates (Duarte *et al.,* 2005). In this context, the term "blue carbon" refers to the potential of coastal carbon sinks to mitigate climate change (Nellemann *et al*., 2009).[2]

It is only with the rising awareness of the international community about the climate change mitigation potential in coastal areas that blue carbon has been devoted attention beyond the biological conservation community (Duarte *et al*., 2008). The characterization of blue carbon as a global public good in the climate change discussions, has multiplied almost by four the production of academic papers on this topic between 2005 and 2012 (Duarte, 2013). However, there is still a need to raise awareness, particularly at the local level, on the benefits of nature-based solutions to address climate change since local managers will commonly opt for on-land mitigation options and (expensive) hard adaptation measures (UICN France, 2016).

The carbon stock in soil in coastal areas is one order of magnitude lower than that under terrestrial forests, but can play an important role on the global carbon cycle since coastal areas can support intense burial rates and can keep the carbon stored for thousands of years in sediments (Fourqurean *et al*., 2012). Mangroves, seagrass meadows, tidal marshes and macroalgae contribute to almost 50% of the carbon burial in marine sediments despite occupying only 0,2% of the ocean surface (Duarte *et al.,* 2013). Besides, some of the co-benefits provided by blue carbon are coastal hazard mitigation, shoreline stabilization and erosion control, safe harbors and sites for maritime industry at shore and offshore, beach production, fisheries production, pollution assimilation, water filtration, and maintenance of water quality and hydrological balances (Agardi, 2004 and Herr *et al.,* 2015). In particular, mangrove forests can be cost-effective alternative solutions to sea-dikes that preserve ecosystems (Berrenstein, 2012).[3][4]

Despite these benefits, between 25% and 50% of the area covered by blue carbon has already been lost in the past 50 years. The management activities that have led to the majority of mangrove loss include forestry activities (26%) and aquaculture, comprising the construction (and extraction of soil) for shrimp ponds (38%) and fish farms (14%) (Vaiela *et al.,* 2009). To our knowledge, this paper is a first contribution to explore the economic growth determinants in countries with blue carbon to explore the effects of potential anthropogenic pressures on these coastal ecosystems.

For this purpose, we build a data set with 23 countries with blue carbon across different regions in the world for the period 1960-2009. There is sufficient knowledge about the fates of ecosystem carbon upon conversion and about country-level geospatial data for mangroves. Our data set therefore only includes countries with high mangrove mitigation potential. To explore the determinants of economic growth in countries with blue carbon, we estimate the augmented Solow model including new growth theories, under a Bayesian moving average methodology that accounts for uncertainty. We note that the

[2] Marine ecosystems and species in the open ocean, i.e. corals, kelp, plankton and marine fauna, play a substantial role in the carbon cycle but they only store carbon temporarily (Laffoley *et al.,* 2014).

[3] About two-thirds of the total adaptation costs for coastal protection come from sea dikes, increasing to over 90% when maintenance costs are considered. Only for coasts, the total global adaptation costs (beach nourishment, port upgrades and capital and maintenance on river and sea dikes) for a scenario of no additional sea-level rise ranges from USD 10,4 billion per year in the 2010s to USD 9,5 billion per year in the 2040s (Nicholls *et al.,* 2010).

[4] Unfortunately, there are not only co-benefits but also risks associated with the impact of the development of blue carbon on other ecosystem services. The potential trade-offs among mitigation objectives, biodiversity and ecosystem services outcomes, and the needs of stakeholders need to be well integrated (Parrotta *et al.,* 2012).

impact of mangroves on the economy is a different research question to the one addressed in this paper, which is better captured through microeconomic analyses (see, for instance, Barbier and Cox, 2004).

In the following section, we detail our contribution to the empirical literature on the determinants of economic growth. In section 3, we describe the econometric model and some preliminary tests. We then examine blue carbon countries' specificities and we estimate the determinants of economic growth under uncertainty. In section 4, we conclude. The appendix provides a detailed description of the data and the estimations.

2. Economic growth determinants

According to neoclassical growth theory output per worker will converge around the world, with areas under low capital-labor ratios having higher rates of return to capital and attracting capital until they eventually catch-up with more advanced economies (Solow, 1956). However, evidence highlights that rapid productivity growth was never sustained in the poorer regions of the world. Indeed, there has been little unconditional convergence in output around the world and most capital investment has gone to developed countries. Under these premises, conditional convergence was defined such that output per worker would not converge to a common level unless other factors coincide.

In order hence to increase the explanatory power of the neoclassical growth models to show how growth rates differ across time and countries, new factors or "new growth theories" were introduced on empirical models to address the unexplained part of growth. Durlauf *et al.* (2008a) developed an exhaustive survey of the empirical growth literature and identified a total of 43 growth theories and 145 regressors. Each of these theories through the associated regressors is found to be statistically significant in at least one study (Durlauf *et al*., 2005). There is therefore empirical evidence in favor of conditional convergence where less favored countries would growth at faster rates until they have reached a steady state under the assumption of decreasing returns to scale. In addition, there may be multiple growth regimes, each one with economies that tend to converge to one another (Durlauf and Johnson, 1995), which requires dividing the sample through the use of several methodologies.[5]

Given the potentially unlimited number of new growth theories, uncertainty is a fundamental problem when analyzing the determinants of economic growth. From an econometric perspective, regression analyses show that a large number of variables are correlated with economic growth but this is far from implying the direction of causation. The lack of agreed theoretical bases for empirical work and for a reduced form to apply in empirical analyses, has led researchers to abandon any a priori models and to let the data show which variables are correlated with economic growth through model uncertainty (Capolupo, 2009). In order to estimate accurately the relevance of new growth theories in determining economic growth, Durlauf *et al.* (2005, 2008a) and Sala-i-Martin *et al.* (2004) propose the BMA methodology which is a Bayesian model averaging method that accounts for uncertainty.[6]

In Table 1, we see that new growth theories can be classified into two classes of theories: proximate and fundamental or deep theories (Rodrik, 2003). According to Durlauf *et al.* (2008a), beyond neoclassical theory, demography, macroeconomic policy, regional heterogeneity are proximate theories, and religion, natural capital, geography, fractionalization and institutions are fundamental theories, the latter theories broadly corresponding to cultural and natural determinants. Proximate theories are associated the production factor inputs, which are human and physical capital, and the productivity with which these endowments are deployed to produce a flow of goods and services (Rodrik, 2003). They can also include additional determinants that can be rapidly influenced by policy measures (Durlauf *et al*.,

[5] See Owen *et al.* (2007) and Konte (2013) for a literature review on how to address multiple growth regimes. There are a number of studies that employ a wide variety of statistical methods in attempting to identify multiple growth regimes (Durlauf *et al.*, 2005).

[6] Fernandez *et al.* (2001) show the superiority of BMA over other techniques in selecting regressors to explain cross-country growth.

2008b). The fundamental or deep sources of growth relate to those variables that have an important influence on a country's ability to accumulate factors of production and invest in the production of knowledge (Acemoglu *et al.*, 2005). In contrast with proximate determinants, fundamental determinants tend to depend on slow-moving parameters (Durlauf *et al*., 2008b). All these theories are not necessary alternative, they can be complementary. Their relevance and linkages can vary among countries.

A proxy variable is used to represent an unobserved metric, that is, the growth theories, and should be strongly correlated with the unobserved corresponding theory. For example, life expectancy and fertility rate are proxy variables strongly correlated with the demography theory. While proxy variables will rarely be perfect estimations for the unobserved theory, they still provide a worthwhile approximation for a necessary variable in the growth model. When there are several proxies within a theory, one can examine separately the effect of each proxy. For example, it is possible to explore whether the eastern religion has a significant impact on economic growth, relative to the other religions examined.

To which extent these proximate and fundamental growth theories apply to countries with blue carbon? From the standpoint of coastal countries, Smith (1776) already stressed the relationship between the geographical location, international trade and economic growth in countries with access to the sea. Besides, countries with a longer coastline are likely to have more ports, a larger share of the population with relatively easy access to the sea, and a greater proportion of economic activity grounded in international trade (Bloom and Sachs, 1998, Masters and Sachs, 2001 and Bloom *et al.*, 2003). Economic policy choices also depend on geography. A coastal economy, for example, may face a higher elasticity of output response with respect to trade taxes than a landlocked economy (Gallup *et al.*, 1998). In addition, more ocean-accessible regions in the world are more urbanized and have lower transport costs (Gallup *et al.*, 1998). However, the relevance of these different growth theories within the context of our sample of coastal countries should be analyzed.

Table 1. Proximate and fundamental growth theories and some proxies

Proximate theories	**Proxies**
Neoclassical	Initial income, population growth rates, investment in physical capital and schooling (Solow, 1956)
Demography	Life expectancy, fertility rate (Shastry and Weil, 2003 and Weil, 2005)
Macroeconomic policy	Openness, government consumption and inflation (Barro, 1997)
Regional heterogeneity	Latin America and Caribbean, Sub-Saharan Africa, East Asia and the Pacific and South-East Asia (Brock and Durlauf, 2001)
Fundamental theories	**Proxies**
Religion	Buddhism, catholic, eastern religion, hindu, jew, muslim, orthodox, protestant and other (Barro and McCleary, 2003, Durlauf *et al.*, 2012)
Natural capital	Natural capital in wealth (which corresponds to economic dependence), natural capital per capita (which reflects economic abundance) (Sachs and Warner, 1995 and Gylfason, 2011), average foot-print per capita and (which captures social dependence on world natural capital)
Geography	Coastline, landlocked (Sachs, 2003)
Fractionalization	Language and ethnic (Alesina *et. al.*, 2003 and Easterly and Levine, 1997)
Institutions	Liberal democracy, public sector corruption, legal formalism, governance and executive constraints (Djankov *et al.*, 2002, 2003)

To our knowledge, we propose in this paper a first contribution to have a better understanding of determinants of economic growth in countries that are concerned with blue carbon, to identify the effects of potential anthropogenic pressures on these coastal ecosystems might impair economic growth. Using a sample of countries with high annual mangrove mitigation potential across different regions in the world, we estimate the augmented Solow model including new growth theories. Such an analysis enables to

compare our results with those of Recuero Virto and Couvet (2017) which apply the same methodology but using a worldwide data set. The latter analysis finds the robust determinants of economic growth are neoclassical (initial income), demography, religion and institutions theories (with a direct impact on economic growth), as well as the fractionalization theory (with an indirect impact on economic growth through demography variables).

3. Empirical analysis

3.1. Econometric methodology

In the following lines, we firstly present the baseline model based on the augmented Solow model and a set of new growth theories. Secondly, we explain how we integrate theory and specification uncertainty through the BMA methodology. Lastly, we explain how we perform our preliminary tests.

Economic growth model: Baseline with eight fundamental and proximate theories

Many economic growth models are estimated using panel data to multiply the number of observations. Since the variation of growth rates at annual frequency rates may give very misleading information about the long-term growth process, we average data over five year periods.[7] Based on Durlauf and Quah (1999), we use the following augmented Solow model with a set of new growth theories (Solow, 1956 and Durlauf *et al.*, 2005, 2008a):

$$\log(y_{i,r}) = \gamma_0 \log(y_{i,r-T}) + \gamma_1 \log(s^k_{i,r}) + \gamma_2 \log(s^h_{i,r}) + \gamma_3 \log(n_{i,r} + g + \delta) + z_{i,r} + \alpha_i + \theta_r + \varepsilon_{i,r} \quad [1]$$

$$\gamma_1 = e^{\lambda T} \quad \gamma_2 = (1 - e^{\lambda T}) \frac{\alpha_k}{1-\alpha_k-\alpha_h} \quad \gamma_3 = (1 - e^{\lambda T}) \frac{\alpha_h}{1-\alpha_k-\alpha_h} \quad \gamma_4 = -(1 - e^{\lambda T}) \frac{\alpha_k+\alpha_h}{1-\alpha_k-\alpha_h}$$

where y_{ir} is the real per capita GDP for country i = [1,.. N] across a time period r = [r, r+T], T being 5 years, $s^k_{i,r}$, $s^h_{i,r}$ and $\log(n_{i,r} + g + \delta)$ denote the variables that measure the net factor accumulation in the neoclassical growth theory with the saving rates of physical capital accumulation ($s^k_{i,r}$) and human capital accumulation ($s^h_{i,r}$) and with population growth rates ($n_{i,r}$), the rate of labor augmenting technical progress (g) and the physical capital depreciation rate (δ), $z_{i,r}$ denotes a set of variables proxying eight new growth theories described in the data subsection and in the appendix (Tables A2 and A3), α_i is a country-specific effect, θ_r is a time-specific effect and $\varepsilon_{i,r}$ is the error term.[8]

Note that typically $g + \delta = 0.05$ (Mankiw *et al.*, 1992). α_k and α_h are the parameters associated with the Cobb-Douglas production function on physical and human capital input variables, such that $\alpha_k > 0, \alpha_h > 0$ and $\alpha_k + \alpha_h < 1$. λ is a parameter that denotes the rate of convergence such that $\lambda < 0$. Saving rates of physical capital accumulation and saving rates of human capital accumulation are referred to hereafter as investment in physical capital and schooling, respectively. Each growth theory can be proxied by several variables within $z_{i,r}$ (see Table 1).

Our economic growth regressions include both proximate and fundamental theories. A theory will be said to be explanatory for growth when there is at least one variable belonging to this theory which has

[7] We have replicated the analysis with 10 year periods but the sample size is too small given the nature of our data (presence of heteroskedasticity and serial correlation). Even though averaging over the longest time horizon possible should better deal with eliminating business cycle effects that probably dominate per capita income fluctuations at higher frequencies, it comes at the cost of reducing the sample size (Durlauf *et al.*, 2008b). In turn, when the sample size is too limited and the number of explanatory variables large, estimation methods can be of limited use to distinguish robust from irrelevant variables.

[8] We note that in our economic growth regressions we replace the country-specific effect variables by the regional heterogeneity variables included in the new growth theories which enables us to take into account regional heterogenity while decreasing the number of variables in the regression given the short number of observations typically associated with economic growth estimations.

a significant impact on growth. Fundamental variables, within the corresponding theories, can have direct and/or indirect effects on economic growth. To examine direct effects, we first develop estimations including both proximate and fundamental variables. If fundamental theories are significant in these estimations, this implies that the corresponding variables have a direct impact on economic growth. To examine indirect effects of fundamental theories on economic growth, we develop estimations including only fundamental theories. When fundamental theories are significant, while they were not significant in the estimations with proximate and fundamental theories, it is possible to infer that such fundamental theories have an indirect impact on economic growth through proximate theories. Correlations between proximate and fundamental theories are also explored, to provide some alternative evidence of relationships between these two kinds of theories.

Economic growth model: Uncertainty

To get a clearer picture of the relevance of the different theories, our approach is to estimate the probability that the different growth theories are relevant through model uncertainty. Such probability contributes to hierarchize their relevance. Notice the advantages compared to the approach where one examines crudely if a theory, through the associated proxies, is significant or not, with a 'yes' or 'no' answer and no hierarchy [11] (Brock and Durlauf, 2001, Brock *et al.*, 2003).

In our approach, we treat the growth model as an unobservable variable. To account for this variable, each model specification m in the model space M is associated with a posterior model probability $\mu(m|D) \propto \mu(D|m)\ \mu(m)$, where D is the available data, $\mu(D|m)$ is the likelihood of the data given the model and $\mu(m)$ is the prior model probability. We set the prior probability that a particular theory is in the true model to 0,5 to reflect non-information across theories (Durlauf *et al.*, 2008a).[9] The posterior model probability is the probability that model m is the true model given the data and it is possible to calculate whether a theory is in the true model by computing $\sum \{m \in M\}\ \mu(m|D, m \in A)$, where A is the event that at least one proxy variable is in the true model.

3.2. Data

The unbalanced panel data set covers 23 countries with high annual mangrove mitigation potential across different regions in the world for 10 five-year periods from 1960 to 2009 (see Table A1 in the appendix). Since there is only country-level geospatial data for mangroves, this represents the only coastal ecosystem for which its is currently possible derive analyses on their mitigation potential and identify priority areas with precision.[10] The annual mitigation potential for mangrove ecosystems at current conversion rates would enable to offset 2,3 to 6,8 % of the current fossil fuel emissions, over half of that projected for reducing rainforest deforestation (Nellemman *et al.*, 2009).

Evidence suggests that there is scope for obtaining significant mitigation through these ecosystems since much of the mangrove mitigation potential lies in a small group of countries. Almost 80 % of mangrove mitigation potential resides in a few countries whose annual mitigation potential is over 3 million t CO2e, 55 % of that potential resides in seven countries with at least five million t CO2e (Murray *et al.*, 2011). Otherwise, the choice of the eight growth theories and the associated variables is largely inspired by the work of Durlauf *et al.* (2008a) and enables to compare results with those of Recuero Virto and Couvet (2017) based on a worldwide data set. The detailed definition of the variables, their designation and the data sources are given in Tables A2 and A3 in the appendix.

[9] Assigning equal prior probability to each possible model can have odd implications for linear regressions with a large number of potential regressors, though. However, the number of variables we are including is not very large compared to other analyses, since we are building over Durlauf *et al.* (2008a) results.

[10] Besides data availability constraints, there are still large sources of uncertainty in the rates of land use conversion and the fates of coastal vegetated ecosystem carbon upon conversion (Duarte, 2014, Pendleton *et al*., 2012). A key question about carbon is where it comes from and what happens to it when the ecosystem releases it. In the case of seagrass meadows, for instance, scientists ignore whether the carbon released from sediments when seagrass dies goes into the atmosphere or remains somewhere else nearby or simply contributes to increased ocean acidification.

3.3. Preliminary results

Compared with Recuero Virto and Couvet (2007)'s worldwide data set, the sample in this paper based on countries with blue carbon is characterized by lower initial income, lower investment in education, higher fertility rates, higher natural capital in wealth, lower natural capital per capita, higher ethnolinguistic fractionalization and higher public sector corruption (see Tables 2 and A5). That corresponds to the so-called "developing" countries compared to a worldwide sample of countries. Indeed, based on the World Bank income classification, blue carbon countries are constituted by 5 % of high income countries (compared to 36 %), 39 % of upper-middle income countries (compared to 32 %), 39 % of lower-middle income countries (compared to 32 %) and 17 % of low-income countries (compared to 9 %). Thus, our analysis should also be compared to findings on determinants of economic growth in developing countries, to discriminate to which extent our results are related lower development.

Table 2. Summary statistics: Countries with blue carbon versus a worldwide data set (main differences in median values)

		Countries with blue carbon		Worldwide data set	
Designation	**Variable**	**Median**	**Std. Dev.**	**Median**	**Std. Dev.**
NEOCLASSICAL					
Initial income	*income_in*	7,78	1,01	8,61	1,26
Schooling	*school*	2,85	0,78	3,40	0,78
DEMOGRAPHY					
Fertility rate	*fertility*	1,64	0,38	1,32	0,52
NATURAL CAPITAL					
Natural capital in wealth	*natural_w*	0,30	0,20	0,17	0,32
Natural capital per capita	*natural_pc*	0,04	0,06	0,09	0,23
FRACTIONALISATION					
Ethnic tensions	*ethnic*	0,55	0,19	0,42	0,26
INSTITUTIONS					
Liberal democracy	*democracy*	0,27	0,20	0,38	0,29
Public sector corruption	*corruption*	0,63	0,24	0,40	0,29
KKZ96	*KKZ96*	-0,37	0,54	0,08	0,90
Executive constraints	*exe_constr*	4,00	1,92	5,00	2,22
OTHER					
Latitude	*latitude*	0,14	0,09	0,22	0,19
Mineral stocks	*minerals*	-7,22	2,26	-6,25	2,96
System	*system*	0,00	0,75	0,55	0,89

In our preliminary analysis, we also find that the data shows heteroskedasticity and serial correlation which need to be taken into account in our analyses. Finally, the correlation matrix conveys some useful information on the explanatory power of fundamental theories in the economic growth regression. It may be the case that the influence of some of the fundamental theories (religion, natural capital, fractionalization and institutions) on economic growth is exerted through proximate theories, and that these fundamental theories may have no direct impact on economic growth. The preliminary analysis results are discussed in detail in the appendix (see Tables A4-A6).

3.4. Economic growth regression results: Countries with blue carbon versus a worldwide data set

In the following lines, we present our findings for the augmented Solow model and eight new growth theories based on equation [1], in relative terms to Recuero Virto and Couvet (2017)'s results based on a worldwide data set.[11][12]

Economic growth determinants: The results that differ between the two samples of countries

In Tables 3 and A7 in the appendix, we see that there are two additional robust new growth theories when using the sample of countries with blue carbon compared to the worldwide data set: macroeconomic policy and natural capital. Indeed, in terms of the fundamental theories, the posterior probability of inclusion is close to one for these two growth theories, both for the estimation with proximate and fundamental theories and for fundamental theories alone. Concerning macroeconomic policy, the result in this paper backs the relevance of macroeconomic policy in coastal countries due to the role of international trade (Gallup *et al*., 1998).

Table 3. Economic growth determinants: BMA posterior inclusion probability results

	Proximate and fundamental theories		**Fundamental theories**	
	Blue carbon	**Worldwide data set**	**Blue carbon**	**Worldwide data set**
DEMOGRAPHY	**0,980**	**1,000**		
MACROEC. POLICY	**0,999**	0,028		
REGIONAL HETERO.	0,089	0,085		
RELIGION	0,264	**0,981**	0,524	**1,000**
NATURAL CAPITAL	**0,999**	0,250	**1,000**	0,227
GEOGRAPHY	0,086	0,056	0,089	0,035
FRACTIONALISATION	0,624	0,056	0,189	**0,964**
INSTITUTIONS	0,366	**1,000**	**0,836**	**1,000**

Note: This table provides the summary results for the posterior inclusion probability for the eight growth theories for the growth regression exercise in equation (1) of the text. The dependent variable is the average growth rate of real per capita GDP corresponding to 10 five-year periods, from 1960 to 2009 for 23 countries with blue carbon. The value in bold indicates that the variable is a relatively robust determinant of economic growth, with robustness increasing as the probability gets close to 1.

In terms of natural capital, the results in this paper are consistent with the findings of Ding and Field (2005) and Cerny and Filer (2007). As we see in Table A3, our natural capital variable is composed of renewable resources (timber, non-timber forest resources, protected areas, cropland and pastureland) and non-renewable resources (oil, natural gas, hard coal, soft coal and minerals). Therefore, our results provide

[11] The ratio of observations to independent variables should not fall below five (Bartlett *et al.*, 2001). As in Durlauf *et al*. (2005), we therefore exclude from the BMA regressions the variables which have weaker explanatory power in our regressions with respect to those presented in Table A2 (some religion variables: buddhism, catholic, jew and orthodox). We check for multicollinearity whereby additional variables are also excluded from the BMA regressions (some regional heterogeneity variables: East Asia and the Pacific and some institutional variables: liberal democracy, public sector corruption, legal formalism: Check (1), legal formalism: Check (2) and complex).

[12] Table A7 shows BMA results for the case where we include both proximate and fundamental determinants in the model space (columns 1-3) as well as the case where only fundamental growth determinants are in the model space (columns 4-6). Columns 1 and 4 provide the posterior probability that each theory is in the 'true' model under the BMA method. In Table 3, we share the summary findings for the BMA posterior inclusion probability for countries with blue carbon and for a worldwide data set.

evidence of a relationship between agriculture and natural resource extraction and economic growth, as previously observed in the empirical literature (Gylfason, 2011).[13]

In Tables 3 and A7, we also see that there are two robust new growth theories when using the worldwide data set that there are not present with the sample of countries with blue carbon: religion and fractionalization. In Table 3, the associated variables to the religion theory do not appear to matter for economic growth in the sample of countries with blue carbon since the posterior probability of inclusion is lower than the prior of 0,5 when accounting for proximate and fundamental theories. These results appear to contradict previous work in the empirical literature suggesting an important role for religion in growth (Barro and McCleary, 2003). Concerning the fractionalization theory, results in this paper differ from previous work in the empirical literature, the latter suggesting an important role for fractionalization in economic growth (Easterly and Levine, 1997 and Alesina et *al.,* 2003).

Otherwise, within the neoclassical theory, investment in physical capital is a robust determinant of economic growth when using the sample of countries with blue carbon, while it is not relevant with the worldwide data set. There is evidence that investment in physical capital is positively and significantly correlated to economic growth in this paper, in line with previous findings (see, for example, Barro, 1991, Barro and Lee, 1994, Sachs and Warner, 1995, Barro, 1996, Caselli *et al.*, 1996 and Barro, 1997).

Economic growth determinants: The results that are common to the two samples of countries

In addition, in Tables 3 and A7, we see that there are three common robust growth theories when using the sample of countries with blue carbon and the worldwide data set: demography, institutions and neoclassical (initial income) theories.[14] With regards to demography variables, in Table A6, we see that the effect of fertility is detrimental to economic growth and significant as in Barro (1991, 1996 and 1997) and Barro and Lee (1994). We note that fertility might not impact (negatively) growth directly, but might be a proxy, for example, for the (in)efficiency of social policies such as the absence of social security for the elders. Our results on institutions in this paper point out that they have a role on economic growth in line with previous empirical literature (Acemoglu *et al.*, 2002). In particular, institutions would matter for economic growth only when fundamental growth theories are considered (Table 3). That is, the impact of institutions on economic growth would be exerted indirectly through proximate theories which are consistent with our preliminary analysis.

In terms of the neoclassical growth variables, our findings are consistent with those in the conditional convergence literature as well as with previous studies that have used BMA methods. We find robust evidence of conditional convergence with a negative and significant coefficient on initial income as many previous studies (Table 6).[15] On the other hand, schooling and population growth are not robust determinants of economic growth independently of the sample of countries used in the estimations. The effect of schooling in this paper, for instance, is not significant which remains largely consistent with the literature (Durlauf *et al.,* 2008a). In exercises where we drop demography from the model space in this

[13] We use variables that proxy national natural capital dependence and abundance suggested by Gylfasson (2011), that is, national natural capital in wealth and national natural capital per capita, respectively (World Bank, 2006). These two variables usually do not have the same impact on economic growth, as a too strong dependence on agriculture and natural resource extraction is typically correlated with low economic growth, while a high ecological abundance in per capita terms should contribute positively to wealth (Gylfason, 2011). Renewable and non-renewable resources were taken into account as separate variables in regressions that can be shared upon request. These regressions conveyed no additional information with respect to the results in Table 3 concerning our research question.

[14] Regional heterogeneity and geography are not robust new growth theories independently of the sample of countries used in the estimations.

[15] See, for instance, Barro (1991), Sachs and Warner (1995), Barro (1997) and Easterly and Levine (1997).

paper, we find that population growth rates are negatively and significantly related to growth (Mankiw *et al.*, 1992, Kelley and Schmidt, 1995 and Blooms and Sachs, 1998).[16]

4. Discussion

In this paper, we make a first contribution to the determinants of economic growth in countries with blue carbon in order to explore the effects of potential anthropogenic pressures on these coastal ecosystems. We find evidence that the neoclassical theory (the initial income and the investment in physical capital variables) as well as the demography, the macroeconomic policy and the natural capital theories are the robust determinants of economic growth in countries with blue carbon. In contrast, the investment in physical capital variable, and the macroeconomic policy and the natural capital theories are not relevant when using a worldwide sample of countries (Recuero Virto and Couvet, 2017). Our results on the role of natural capital on economic growth are largely consistent with the empirical literature on the economic growth determinants in developing countries, whereby developing countries are typically characterized by low national natural capital abundance in per capita terms and high economic dependence on national natural capital (Gylfason, 2011).

Compared to an average country the value of national natural capital per capita is reduced by more than half and there is evidence in the empirical literature that this is limiting factor for economic growth (Tables 2 and A5). In addition, there is also empirical evidence that a too strong economic dependence on national natural capital, almost two times higher than in an average country in our case, has a negative impact on economic growth (Gylfason, 2011). This negative link is mainly associated in the empirical literature with the export of non-renewable resources and the associated 'resource curse' (see, for instance, van der Ploeg, 2010 and Ross, 2014).[17] At the same time, the macroeconomic policy theory is a relevant determinant of economic growth in these countries with open access to the sea. Indeed, there is a relationship between international trade and economic policy choices, and economic growth in countries with access to the sea (Smith, 1776 and Gallup *et al.*, 1998).

Our results on the role of natural capital exploitation, together with the high fertility rates in countries with blue carbon, highlight the potential anthropogenic pressures that coastal areas with blue carbon can be subject to such as land conversion for agriculture or aquaculture, farming run-offs, over-exploitation of blue carbon resources, urbanization, uncontrolled sewage and public works which, in turn, can degrade blue carbon ecosystems. In fact, since countries with blue carbon are characterized by high demographic growth, blue carbon ecosystems have higher probability of being eroded for short-term gain which is still often preferred to ecosystem services management (Larrère and Larrère, 1997 and MEA, 2005). An increasing population raises anthropogenic pressures on coastal ecosystems, through increases in direct exploitation as well as through the exacerbation of indirect effects such as uncontrolled sewage or farming runoffs (Cinner *et al.*, 2009 and Bond Estes *et al.*, 2012).

Given these findings, we highlight the role of central governments to provide incentives for the protection of these nature-based solutions at the level of local policy makers and communities (Naumann *et al.*, 2011). Due to the budgetary constraints that often characterize these developing countries, international financial institutions can provide financial support to such initiatives. These nature-based solutions can be considered as climate mitigation and adaptation tools and can result on additional co-benefits for societal well-being, thereby being relevant investment options for sustainable urban planning in coastal areas (Kabisch *et al.*, 2016). Ecosystem-based approaches have the potential to be more cost-effective, particularly in the long-run, compared to grey infrastructure solutions.

[16] Results are available upon request.

[17] Depending on institutional factors, this type of relationship based on export dependence can be reversed (Dinh and Dinh, 2016).

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6. Appendix

Data

The data set constructed for this study contains observations on 23 mangrove countries with high annual mangrove climate change mitigation potential for the period 1960-2009 on the following countries listed in Table A1 for which we have sufficient data on neoclassical variables.

Table A1. Top 25 mangrove countries according to the annual mangrove climate change mitigation potential

Countries	Discounted annual mangrove mitigation potential (million tCO2e/year)
Indonesia	30.679.644
Mexico	8.137.233
Papua New Guinea	4.570.866
Malaysia	4.181.896
Vietnam	2.564.008
Colombia	2.261.764
Pakistan	2.026.638
United States	1.953.947
Guinea-Bissau*	1.832.201
Myanmar*	1.790.324
Philippines	1.762.242
Sierra Leone	1.716.291
Gabon	1.698.338
Honduras	1.631.183
Madagascar	1.539.227
Senegal	1.342.843
India	1.133.760
Venezuela	1.124.822
Panama	1.056.887
Tanzania	755.870
Ecuador	684.104
Nicaragua	681.651
Brazil	872.828
Cambodia	692.276
Thailand	603.800

Note: (*) indicates the countries that have been excluded from the analysis due to lack of sufficient data.
Source: Author based on Murray *et al.* (2011).

We have collected data on variables regrouped in five categories: neoclassical, demography, macroeconomic policy, regional heterogeneity, religion, natural capital, geography, fractionalization, institutions and other. The definition of these variables and the data sources are given below.

Table A2. Data description

Designation	Source(s)
NEOCLASSICAL	
Growth rates of pc GDP	Average growth rates (constant 2005 USD prices) for the periods 1960-1964, 1965-1969, 1970-1974, 1975-1979, 1980-1984, 1985-1989, 1990-1994, 1995-1999, 2000-2004 and 2005-2009.
Initial income	Logarithm of real GDP per capita (constant 2005 USD prices) at 1960, 1965, 1970, 1975, 1980, 1985, 1990, 1995, 2000 and 2005. The instruments for the initial income include the values at 1955, 1960, 1965, 1970, 1975, 1980, 1985, 1990, 1995 and 2000.
Population growth rates	Logarithm of average population growth rates plus 0.05 for the periods 1960-1964, 1965-1969, 1970-1974, 1975-1979, 1980-1984, 1985-1989, 1990-1995, 2000-2004 and 2005-2009. The instruments for populations growth rates include the average values of 1955-1959, 1960-1964, 1965-1969, 1970-1974, 1975-1979, 1980-1984, 1985-1989, 1990-1995 and 2000-2004.
Investment in physical capital	Logarithm of average ratios over each period of investment in physical capital to GDP for the periods 1960-1964, 1965-1969, 1970-1974, 1975-1979, 1980-1984, 1985-1989, 1990-1995, 2000-2004 and 2005-2009. The instruments for investment include the average values of 1955-1959, 1960-1964, 1965-1969, 1970-1974, 1975-1979, 1980-1984, 1985-1989, 1990-1995 and 2000-2004.
Schooling	Logarithm of the ratio of male population enrolled in secondary school to total population in 1960, 1965, 1970, 1975, 1980, 1985, 1990, 1995, 2000 and 2005.
DEMOGRAPHY	
Life Expectancy	Reciprocals of life expectancy at age 1 in 1960, 1965, 1970, 1975, 1980, 1985, 1990, 1995, 2000 and 2005.
Fertility rate	The log (LN) of the total fertility rate in 1960, 1965, 1970, 1975, 1980, 1985, 1990, 1995, 2000 and 2005.
MACROECONOMIC POLICY	
Openness	Average ratios for each period of exports plus imports to GDP in 1960-1964, 1965-1969, 1970-1974, 1975-1979, 1980-1984, 1985-1989, 1990-1994, 1995-1999, 2000-2004 and 2005-2009. The instruments include the average values of 1955-1959, 1960-1964, 1965-1969, 1970-1974, 1975-1979, 1980-1984, 1985-1989, 1990-1995 and 2000-2004.
Government consumption	Average ratios for each period of government consumption to GDP in 1960-1964, 1965-1969, 1970-1974, 1975-1979, 1980-1984, 1985-1989, 1990-1994, 1995-1999, 2000-2004 and 2005-2009.
Inflation	The consumer price inflation rate for the periods 1960-1969, 1970-1979, 1980-1989, 1990-1999 and 2000-2009.
REGIONAL HETEROGENEITY	
Latin America and Caribbean	Dummy variable.
Sub-Saharan Africa	Idem.
South-East Asia	Idem.

RELIGION	
Buddhism	Buddhism share in 1970 expressed as a fraction of the population who expressed adherence to some religion. The instruments include the Buddhism share in 1900 expressed as a fraction of the population who expressed adherence to some religion.
Catholic	Catholic share in 1970 expressed as a fraction of the population who expressed adherence to some religion. The instruments include the catholic share in 1900 expressed as a fraction of the population who expressed adherence to some religion.
Eastern Religion	Eastern Religion share in 1970 expressed as a fraction of the population who expressed adherence to some religion. The instruments include the eastern religion share in 1900 expressed as a fraction of the population who expressed adherence to some religion.
Hindu	Hindu share in 1970 expressed as a fraction of the population who expressed adherence to some religion. The instruments include the Hindu share in 1900 expressed as a fraction of the population who expressed adherence to some religion.
Jew	Jew share in 1970 expressed as a fraction of the population who expressed adherence to some religion. The instruments include the Jew share in 1900 expressed as a fraction of the population who expressed adherence to some religion.
Muslim	Muslim share in 1970 expressed as a fraction of the population who expressed adherence to some religion. The instruments include the Muslim share in 1900 expressed as a fraction of the population who expressed adherence to some religion.
Orthodox	Orthodox share in 1970 expressed as a fraction of the population who expressed adherence to some religion. The instruments include the orthodox share in 1900 expressed as a fraction of the population who expressed adherence to some religion.
Other	Other religion share in 1970. The instruments include the other religion share in 1990.
Protestant	Protestant share in 1970 expressed as a fraction of the population who expressed adherence to some religion. The instruments include the protestant share in 1900 expressed as a fraction of the population who expressed adherence to some religion.
NATURAL CAPITAL	
Natural capital in wealth	Time-invariant variable measuring the weight of natural capital in total wealth in 2000.
Natural capital per capita	Time-invariant variable measuring natural capital per capita in 2000. The variable is scaled to take values between zero and one.
GEOGRAPHY	
Coastline	Coastline length in km, scaled to take values between zero and one.
FRACTIONALISATION	
Language	Time-invariant measure of linguistic fractionalization that reflects the probability that two randomly selected individuals from a population belong to different groups. The data ranges from 0-1.
Ethnic	Time-invariant measure of ethnic fractionalization that reflects the probability that two randomly selected individuals from the population belong to different groups. The data ranges from 0-1.

INSTITUTIONS	
Liberal democracy	Time variant-index that emphasizes the importance of protecting individual and minority rights against the tyranny of the state and the tyranny of the majority. This is achieved by constitutionally protected civil liberties, strong rule of law, an independent judiciary, and effective checks and balances that, together, limit the exercise of executive power. To make this a measure of liberal democracy, the index also takes the level of electoral democracy into account. This variable is calculated as the average for the periods 1960-1965, 1965-1970, 1970-1980, 1980-1985, 1985-1990, 1990-1995, 1995-2000, 2000-2005 and 2005-2009. It ranges from zero to one. Higher scores imply a more liberal democracy.
Public sector corruption	Time-variant variables that measures to what extent public sector employees grant favors in exchange for bribes, kickbacks, or other material inducements, and how often they steal, embezzle, or misappropriate public funds or other state resources for personal or family use. This variable is calculated as the average for the periods 1960-1965, 1965-1970, 1970-1980, 1980-1985, 1985-1990, 1990-1995, 1995-2000, 2000-2005 and 2005-2009. It ranges from zero to one. Higher scores imply a more corruption.
Legal formalism: Check (1)	Time-invariant index of the professionals vs. laymen, written vs. oral elements, legal justification, statutory regulation of evidence, control of superior review, and engagement formalities indices, and the normalized number of independent procedural actions for the case of collection of a check. The index ranges from zero to seven, where seven means a higher level of control or intervention in the judicial process.
Legal formalism: Check (2)	Time-invariant index of formality in legal procedures for collecting on a bounced check, rescaled to lie between zero to one for 2003. Lower scores imply a less legal formality.
Complex	Time-invariant index of complexity in collecting a commercial debt valued at 50 % of annual GDP per capita, rescaled to lie between zero and one for 2003. Lower scores imply a less complexity.
KKZ96	Time-invariant composite governance index. It is calculated as the average of six variables: voice and accountability, political stability and absence of violence, government effectiveness, regulatory quality, rule of law, and control of corruption in 1996. It ranges from –2 to 2. Higher values imply better governance.
Executive constraints	Time varying variable that measures the extent of institutionalized constraints on the decision making powers of chief executives. This variable is calculated as the average for the periods 1960-1965, 1965-1970, 1970-1980, 1980-1985, 1985-1990, 1990-1995, 1995-2000, 2000-2005 and 2005-2009. This variable ranges from zero to seven where higher values equal a greater extent of institutionalized constraints on the power of chief executives.
OTHER	
Time dummy variables	Dummy variables for 1960-1965, 1965-1970, 1970-1980, 1980-1985, 1985-1990, 1990-1995, 1995-2000, 2000-2005 and 2005-2009
Colonial (Spain or Portugal)	Binary variable where one indicates that country was colonized by Spain or Portugal.

English legal origin	Binary variable where one indicates that country was colonized by The United Kingdom, and English legal code was transferred.
French legal origin	Binary variable where one indicates that country was colonized by France, Spain, Belgium, Portugal or Germany and French legal code was transferred.
Latitude	The absolute value of the latitude of the capital of the country, scaled to take values between zero and one.
Mineral stocks	Time-invariant variable that takes the value of the logarithm of fuel and 35 non fossil fuel stocks estimated for 1970 at market prices, in US dollars per capita.
System	Time-invariant variable that takes the value of 0 if the country has a presidential system, 1 if it has an assembly-elected president and 2 if it has a parliamentary system (mean value between 1975 and 2010).

Table A3. Data sources

Designation	**Source(s)**
NEOCLASSICAL	
Growth rates of pc GDP	Penn World Tables 7.1
Initial income	Idem
Population growth rates	Idem
Investment in physical capital	Idem
Schooling	Barro and Lee (2014)
DEMOGRAPHY	
Life Expectancy	World Bank
Fertility rate	Idem
MACROECONOMIC POLICY	
Openness	Penn World Tables 7.1
Government consumption	Idem
Inflation	World Bank
REGIONAL HETEROGENEITY	
Latin America and Caribbean	World Bank country classification
Sub-Saharan Africa	Idem
South-East Asia	Idem
RELIGION	
Buddhism	World Christian Encyclopedia (2001)
Catholic	Idem
Eastern Religion	Idem
Hindu	Idem
Jew	Idem
Muslim	Idem
Orthodox	Idem
Other	Idem
Protestant	Idem
NATURAL CAPITAL	
Natural capital in wealth	World Bank
Natural capital per capita	Idem

GEOGRAPHY	
Coastline	UNEP (2015)
FRACTIONALISATION	
Language	Alesina *et al.* (2003)
Ethnic	Idem
INSTITUTIONS	
Liberal democracy	The QOG Standard Dataset
Public sector corruption	Idem
Legal formalism: Check (1)	Djankov *et al.* (2003)
Legal formalism: Check (2)	Doing Business, World Bank
Complex	Idem
KKZ96	Kaufmann *et al.* (2005)
Executive constraints	Polity IV Project, 1946-2013
OTHER	
Time dummy variables	Own construction
Colonial (Spain or Portugal)	Barro and Lee (1994)
English legal origin	Easterly (2001)
French legal origin	La Porta *et al.* (1999), and Djankov *et al.* (2003)
Latitude	Djankov *et al.* (2003)
Mineral stocks	Norman (2009) and van der Ploeg and Poelhekke (2010)
System	Beck *et al.* (2001)

Descriptive statistics and preliminary results

We share the preliminary analysis results in Tables A4-A6. Firstly, we present the summary statistics and the correlation matrix between the variables that proxy proximate and fundamental economic growth theories. This correlation matrix conveys some information on whether fundamental theories, may have some explanatory power in the economic growth regression, beyond the influence exerted through proximate theories. Secondly, we perform some preliminary tests to prepare the data for the preliminary exploration and the economic growth regressions.

In Tables A4-A6, we share the summary statistics for all the variables that we used in our estimations for countries with carbon and compare them with those of a world wide data set based on Recuero Virto and Couvet (2017). In Table A6, we present the correlation matrix between the proximate theories' variables and the variables associated with the fundamental theories, whenever the level of correlation is above or equal to 0,40. The variables associated with four fundamental theories, religion, natural capital, fractionalization and institutions, are strongly correlated with variables from all proximate theories except for the macroeconomic policy theory. Building on these results, we analyze when running the regressions whether the fundamental theories just mentioned (religion, natural capital, fractionalization and institutions) have some explanatory power in the economic growth regression, beyond the influence exerted through proximate theories' variables. We finally perform a series of preliminary tests. We find that our dependent variable is stationary in levels, that panel data is preferred to pool data and that there is presence of heteroskedasticity and serial correlation, and we treat our data accordingly.[18]

[18] Firstly, through the Fisher unit root test, we find that the dependent variable is stationary in levels. Secondly, we verify whether it is preferable to pool or not the data by testing the appropriateness of random and fixed-effects panel data compared to the pool analysis through the goodness-of-fit results. Panel data is preferred to pool data which implies that the parameters of the equation vary from one period to the other over the ten periods of available data. Thirdly, our data shows heteroskedasticity across panels through the Erlat LM-test and serial correlation through the Baltagi LM-test. The OLS and fixed-effects methods have adjusted standard errors for intragroup correlation which should hence be robust to

Table A4. Summary statistics: Countries with blue carbon

Designation	Variable	Obs.	Median	Mean	Std. Dev.	Min.	Max.
NEOCLASSICAL							
Growth rates of pc GDP	*growth_pc*	226	0,02	0,02	0,03	-0,10	0,12
Initial income	*income_in*	225	7,78	7,87	1,01	5,94	10,65
Population growth rates	*population*	230	-2,65	-2,68	0,10	-3,22	-2,46
Investment	*invest*	225	3,01	2,96	0,48	1,15	4,20
Schooling	*school*	220	2,85	2,80	0,78	-0,23	4,11
DEMOGRAPHY							
Life Expectancy	*life_exp*	230	0,01	0,01	0,00	0,01	0,04
Fertility rate	*fertility*	230	1,64	1,52	0,38	0,43	2,01
MACROECONOMIC POLICY							
Openness	*open*	226	0,53	0,62	0,44	0,07	2,06
Government consumption	*gov_consu*	228	0,08	0,10	0,07	0,02	0,41
Inflation	*inflation*	182	0,07	0,24	1,31	0,00	16,67
REGIONAL HETEROGENEITY							
Latin America and Caribbean	*lac*	230	0,00	0,34	0,47	0,00	1,00
Sub-Saharan Africa	*ssa*	230	0,00	0,21	0,41	0,00	1,00
South-East Asia	*sea*	230	0,00	0,08	0,28	0,00	1,00
RELIGION							
Buddhism	*buddhism*	230	0,00	0,10	0,26	0,00	0,92
Catholic	*catholic*	230	0,22	0,42	0,39	0,00	0,94
Eastern Religion	*eastern*	230	0,00	0,02	0,07	0,00	0,25
Hindu	*hindu*	230	0,00	0,03	0,15	0,00	0,76
Jew	*jew*	230	0,00	0,00	0,00	0,00	0,03
Muslim	*muslim*	230	0,02	0,17	0,28	0,00	0,96
Orthodox	*orthodox*	230	0,00	0,00	0,00	0,00	0,02
Other	*other*	230	0,01	0,06	0,14	-0,16	0,49
Protestant	*protestant*	230	0,03	0,07	0,10	0,00	0,39
NATURAL CAPITAL							
Natural capital in wealth	*natural_w*	200	0,30	0,33	0,20	0,02	0,88
Natural capital per capita	*natural_pc*	200	0,04	0,06	0,06	0,00	0,26
GEOGRAPHY							
Coastline	*coastline*	230	0,02	0,07	0,11	0,00	0,50
FRACTIONALISATION							
Language	*language*	230	0,35	0,41	0,31	0,01	0,89
Ethnic tensions	*ethnic*	230	0,55	0,54	0,19	0,18	0,87
INSTITUTIONS							
Liberal democracy	*democracy*	218	0,27	0,32	0,20	0,02	0,88
Public sector corruption	*corruption*	218	0,63	0,58	0,24	0,02	0,97
Legal formalism: Check (1)	*check(1)*	160	0,47	0,50	0,17	0,22	0,83

heteroskedasticity and serial correlation. The GMM method also controls for heteroskedasticity and we test the presence of serial correlation of order one and two. This method assumes there is no second-order autocorrelation in the error term in levels. To perform the 2SLS method for the economic growth regressions, we use Driscoll and Kraay's approach which guarantees that the covariance matrix estimator is consistent, independently of the cross-sectional dimension, in contrast to Parks-Kmenta and the Panel-Corrected Standard Errors (PCSE) approaches, which typically become inappropriate when the cross-sectional dimension of a microeconometric panel gets large (Driscoll and Kraay, 1998).

Legal formalism: Check (2)	*check(2)*	170	3,90	4,04	1,08	2,34	6,00
Complex	*complex*	220	0,62	0,60	0,14	0,29	0,82
KKZ96	*KKZ96*	230	-0,37	-0,24	0,54	-1,16	1,61
Executive constraints	*exe_constr*	220	4,00	4,17	1,92	0,75	7,00
OTHER							
Time dummy variables	*year_dummy*						
Colonial (Spain or Portugal)	*colonial*	200	0,00	0,40	0,49	0,00	1,00
English legal origin	*english*	230	0,00	0,34	0,47	0,00	1,00
French legal origin	*french*	200	0,00	0,10	0,30	0,00	1,00
Latitude	*latitude*	230	0,14	0,14	0,09	0,01	0,42
Mineral stocks	*minerals*	210	-7,22	-6,99	2,26	-11,59	-2,90
System	*system*	230	0,00	0,58	0,75	0,00	2,00

Table A5. Summary statistics: Countries with blue carbon versus a worldwide data set

		Countries with blue carbon		Worldwide data set	
Designation	**Variable**	**Median**	**Std. Dev.**	**Median**	**Std. Dev.**
NEOCLASSICAL					
Growth rates of pc GDP	*growth_pc*	0,02	0,03	0,02	0,03
Initial income	*income_in*	7,78	1,01	8,61	1,26
Population growth rates	*population*	-2,65	0,10	-2,73	0,19
Investment	*invest*	3,01	0,48	3,11	0,52
Schooling	*school*	2,85	0,78	3,40	0,78
DEMOGRAPHY					
Life Expectancy	*life_exp*	0,01	0,00	0,01	0,08
Fertility rate	*fertility*	1,64	0,38	1,32	0,52
MACROECONOMIC POLICY					
Openness	*open*	0,53	0,44	0,51	0,45
Government consumption	*gov_consu*	0,08	0,07	0,08	0,06
Inflation	*inflation*	0,07	1,31	0,06	1,36
REGIONAL HETEROGENEITY					
Latin America and Caribbean	*lac*	0,00	0,47	0,00	0,42
Sub-Saharan Africa	*ssa*	0,00	0,41	0,00	0,38
South-East Asia	*sea*	0,00	0,28	0,00	0,23
RELIGION					
Buddhism	*buddhism*	0,00	0,26	0,00	0,14
Catholic	*catholic*	0,22	0,39	0,17	0,37
Eastern Religion	*eastern*	0,00	0,07	0,00	0,07
Hindu	*hindu*	0,00	0,15	0,00	0,11
Jew	*jew*	0,00	0,00	0,00	0,09
Muslim	*muslim*	0,02	0,28	0,01	0,34
Orthodox	*orthodox*	0,00	0,00	0,00	0,10
Other	*other*	0,01	0,14	0,00	0,13
Protestant	*protestant*	0,03	0,10	0,04	0,24
NATURAL CAPITAL					
Natural capital in wealth	*natural_w*	0,30	0,20	0,17	0,32
Natural capital per capita	*natural_pc*	0,04	0,06	0,09	0,23
GEOGRAPHY					

Coastline	*coastline*	0,02	0,11	0,01	0,19
FRACTIONALISATION					
Language	*language*	0,35	0,31	0,33	0,29
Ethnic tensions	*ethnic*	0,55	0,19	0,42	0,26
INSTITUTIONS					
Liberal democracy	*democracy*	0,27	0,20	0,38	0,29
Public sector corruption	*corruption*	0,63	0,24	0,40	0,29
Legal formalism: Check (1)	*check(1)*	3,90	1,08	3,39	1,10
Legal formalism: Check (2)	*check(2)*	0,47	0,17	0,38	0,18
Complex	*complex*	0,62	0,14	0,53	0,15
KKZ96	*KKZ96*	-0,37	0,54	0,08	0,90
Executive constraints	*exe_constr*	4,00	1,92	5,00	2,22
OTHER					
Time dummy variables	*year_dummy*				
Colonial (Spain or Portugal)	*colonial*	0,00	0,49	0,00	0,39
English legal origin	*english*	0,00	0,47	0,00	0,49
French legal origin	*french*	0,00	0,30	0,00	0,28
Latitude	*latitude*	0,14	0,09	0,22	0,19
Mineral stocks	*minerals*	-7,22	2,26	-6,25	2,96
System	*system*	0,00	0,75	0,55	0,89

Table A6. Correlation matrix between proximate and fundamental theories: Countries with blue carbon

Fundamen. theories	Proximate theories										
	popu.	*invest*	*scho.*	*life.*	*fert.*	*open*	*gov_.*	*infl.*	*lac*	*ssa*	*sea*
RELIGION											
buddhism	-0,37	**0,41**	-0,14	-0,06	-0,18	0,17	-0,10	-0,05	-0,25	-0,09	-0,12
catholic	0,04	0,02	0,13	-0,32	-0,00	-0,01	-0,10	0,12	**0,86**	-0,26	-0,42
hindu	0,00	-0,00	-0,04	0,31	0,05	-0,21	0,23	-0,05	-0,26	-0,09	**0,71**
jew	-0,35	-0,09	0,38	-0,30	**-0,44**	-0,24	0,09	-0,03	-0,19	-0,09	-0,13
muslim	**0,40**	-0,32	-0,26	**0,42**	0,37	0,09	0,05	-0,07	**-0,51**	**0,55**	0,33
orthodox	-0,37	-0,08	0,36	-0,27	**-0,42**	-0,32	0,06	-0,04	-0,16	-0,12	-0,05
protestant	-0,35	-0,08	**0,41**	-0,34	**-0,46**	-0,16	0,18	0,01	-0,18	-0,18	-0,16
NATURAL CAPITAL											
natural_pc	-0,20	0,31	0,17	-0,34	-0,26	-0,10	-0,12	0,07	**0,51**	-0,28	-0,36
FRACTIONALISATION											
language	0,27	-0,05	-0,17	0,41	0,27	0,20	0,14	-0,16	**-0,83**	0,20	**0,42**
INSTITUTIONS											
democracy	-0,27	-0,19	0,37	-0,27	**-0,54**	-0,25	0,09	0,13	-0,00	0,06	0,06
corruption	0,09	0,20	**-0,47**	0,27	0,29	0,18	-0,11	0,04	0,03	0,17	-0,14
check(1)	0,39	-0,16	-0,13	0,07	0,34	0,22	0,18	-0,11	**0,53**	0,19	-0,04
check(2)	0,37	-0,18	-0,18	0,08	0,35	0,25	0,17	-0,09	**0,51**	0,19	-0,19
complex	**0,40**	-0,18	-0,24	0,15	0,33	0,33	0,20	-0,09	0,31	0,31	-0,30
KKZ96	-0,35	0,15	**0,44**	**-0,41**	**-0,50**	0,08	0,01	-0,04	-0,25	-0,19	-0,32
exe_constr	-0,23	-0,07	**0,43**	-0,26	**-0,46**	-0,18	-0,04	0,02	-0,01	-0,16	0,22

Note: Values are only reported for those variables with a correlation above or equal to 0,40. The correlation matrix with all variables is available upon request to authors.

Results

These tables provide results for the growth regression exercise in equation [1] of the text under BMA regressions with theory and specification uncertainty. The dependent variable is the average growth rate of real per capita GDP corresponding to the periods 1960-64, 1965-69, 1970-74, 1975-79, 1980-84, 1985-89, 1990-94, 1995-99, 2000-04 and 2005-2009. Following Durlauf *et al.* (2008a), we instrument for endogenous variables using earlier or initial values if available with the exception of inflation, religion shares and natural capital under the Two-Stage Least Squares (2SLS) regressions (without uncertainty). For inflation we use as instruments the colonial dummy for Spain or Portugal and British and French legal origins and for religion shares we use the corresponding shares in 1900. Following van der Ploeg and Poelhekke (2010) we used a dummy for presidential system and mineral resource stocks as an instrument for natural capital variables. The 2SLS regression results are very similar to the BMA regression results with uncertainty and are available upon request.

Table A7. BMA estimation results for average growth rates of per capita GDP: Countries with blue carbon

	Proximate and fundamental theories			Fundamental theories		
Explanatory variable	**Posterior inclusion proba. (#)**	**Posterior mean**	**Posterior standard deviation**	**Posterior inclusion proba. (#)**	**Posterior mean**	**Posterior standard deviation**
NEOCLASSICAL						
income_in		-0,072*	0,024		-0,057	0,033
population		0,353	0,263			
invest		0,071*	0,034			
school		-0,002	0,031			
DEMOGRAPHY	**0,980**					
life_exp		-4,365	7,676			
fertility		-0,215*	0,071			
MACROECONOMIC POLICY	**0,999**					
open		0,001	0,008			
gov_consu		-0,015	0,086			
inflation		-0,012*	0,006			
REGIONAL HETEROGENEITY	0,089					
lac		-0,000	0,007			
ssa		-0,003	0,026			
sea		0,002	0,015			
RELIGION	0,264			0,524		
buddhism		0,001	0,012		0,029	0,059
eastern		0,105	0,211		0,232	0,277
muslim		-0,064	0,131		-0,059	0,093
protestant		0,007	0,051		-0,000	0,060
NATURAL CAPITAL	**0,999**			**1,000**		
natural_w		-0,085	0,089		-0,028	0,075
natural_pc		0,097	0,326		0,422	0,376
GEOGRAPHY	0,086			0,089		
coastline		-0,004	0,032		-0,005	0,038
FRACTIONALISATION	0,624			0,189		
language		0,002	0,016		0,001	0,013
ethnic		0,132	0,140		0,027	0,074
INSTITUTIONS	0,366			**0,836**		
KKZ96		0,008	0,026		0,085	0,050
exe_constr		-0,003	0,006		-0,001	0,004
year_dummies		Yes			Yes	
observations		208			208	

Note: This table provides results for the growth regression exercise in equation (1) of the text. The dependent variable is the average growth rate of real per capita GDP corresponding to 10 five-year periods, from 1960 to 2009 for 23 countries with high annual mangrove mitigation potential. "*" denotes significance. Within BMA, a specific theory is important if the posterior mean of the probability is at least twice the posterior standard deviation (see Brock and Durlauf, 2001). "#" denotes the posterior inclusion probability of each theory (as opposed to each individual variable). The value in bold indicates that the variable is a relatively robust determinant of economic growth, with robustness increasing as the probability gets close to 1.