Energy Policy 62 (2013) 1434–1437

Contents lists available at ScienceDirect

Energy Policy

journal homepage: www.elsevier.com/locate/enpol

Communication

Does income inequality harm the environment?: Empirical evidence from the United States

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HIGHLIGHTS

- This study re-examines the growth-inequality-environment nexus in the U.S.
- The autoregressive distributed lag (ARDL) approach is employed.
- Income equality is found to have a beneficial effect on the environment.
- Economic growth is also found to enhance environmental quality.
- But energy consumption is found to have a detrimental effect on the environment.

ARTICLE INFO

Article history:
Received 26 November 2012
Accepted 27 July 2013
Available online 20 August 2013

Keywords:
ARDL
Environment
Inequality

ABSTRACT

This study revisits the growth-inequality-environment nexus in the context of country-specific time series data. The short- and long-run effects of income inequality, economic growth and energy consumption on CO_2 emissions in the U.S. are examined using the autoregressive distributed lag (ARDL) approach. We find that more equitable distribution of income in the U.S. results in better environmental quality in the short- and long-run. It is also found that, in both the short- and long-run, economic growth has a beneficial effect on environmental quality, whereas energy consumption has a detrimental effect on the environment.

1. Introduction

In the literature on environmental economics, the environmental Kuznets curve (EKC) hypothesis plays an important role in analyzing the environmental consequences of economic development (income growth). The EKC postulates an inverted-U shaped relationship between economic growth and certain types of pollution. In examining the EKC, studies initially rely on a simple reduced-form model in which measures of environmental quality (e.g., SO_2 and CO_2 emissions) are specified as only a function of income (e.g., Grossman and Krueger, 1991; Shafik, 1994; Agras and Chapman, 1999).

Recent studies, however, argue that factors other than income also could be the important determinants of environmental outcomes; and earlier studies may suffer from the omitted variable bias (e.g., Iwata et al., 2010; Kim and Baek, 2011). Accordingly, it is a common practice in the recent EKC literature to regress measures of environmental quality on other relevant variables (e.g., energy consumption, foreign direct investment, trade openness) in addition to income variable (e.g., Soytas et al., 2007; Jalil and Mahmud, 2009; Iwata et al., 2010; Kim and Baek, 2011).

Although the recent EKC literature has identified several variables other than income affecting environmental outcomes, *less* widely recognized variable is income distribution (inequality). Boyce (1994) is the first to argue that income distribution significantly affects society′s demand for environmental quality and hence an induced policy response; thus, the income inequality should be accounted for when estimating the EKC hypothesis (known as the *political economy argument*). Several empirical studies have since examined the claim. Torras and Boyce (1998), for example, find the importance of income distribution as an explanatory variable in a model; that is, greater equality of incomes results in lower levels of environmental degradation. Heerink et al. (2001), on the other hand, show that redistributing income has a detrimental effect on the environment. One major limitation of these studies is that they all use cross-section or panel data of a group of countries for their empirical analysis. For this reason, despite the wide variations between countries, they assume that an individual country′s experience over time would mirror the pattern revealed by a group of countries at different stages of economic development and hence income distribution at

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0301-4215/$ - see front matter
http://dx.doi.org/10.1016/j.enpol.2013.07.097

a point in time. No study has adopted country-specific time series data to examine the effect of economic growth on the environment by taking the role of income distribution into account.

In this study, therefore, we attempt to expand the existing literature by re-examining *the growth-inequality-environment nexus* in the context of country-specific time series data. Empirical focus is on assessment of the short- and long-run effects of changes in income per capita and income inequality on changes in CO_2 emissions in the U.S. for a given level of energy consumption.[1] For this purpose, we employ an autogressive distributed lag (ARDL) approach to cointegration developed by Pesaran et al. (2001).

The remainder of this paper is organized as follows. Section 2 briefly presents the empirical framework used for this analysis. Section 3 presents our data. In Section 4 the main empirical findings are reported and discussed. Finally Section 5 makes some concluding remarks.

2. The model

In the empirical model used here we modify a theoretical framework developed by Torras and Boyce (1998) and Heerink et al. (2001) to represent the long-run relationship between CO_2 emissions and its major determinants in a linear logarithmic form as follows:

$$\ln(CO_2)_t = \beta_0 + \beta_1 \ln Y_t + \beta_2 \ln G_t + \beta_3 \ln E_t + u_t \quad (1)$$

where $(CO_2)_t$ is the per capita CO_2 emissions; Y_t is the per capita real income; G_t is the measure of income distribution; E_t is the energy consumption; and u_t is error term. It should be pointed out that, following previous studies, other variables such as foreign direct investment (FDI) and trade openness are also included in the model to capture their impacts on the environment, but are excluded from the final model because of coefficient insignificance. With respect to the signs of the coefficients in Eq. (1), β_1 is expected to be negative (positive), if CO_2 emissions decline (rise) with higher income level. If a more equal distribution of income causes less pollution emissions, the sign of β_2 is expected to be positive. Finally, if energy consumption leads to an increase in CO_2 emissions through greater economic activity, the sign of β_3 is expected to be positive.

To implement the bounds testing procedure, following Pesaran et al. (2001), it is necessary to reformulate Eq. (1) as a conditional autoregressive distributed lag (ARDL) model as follows:

$$\begin{aligned}\Delta\ln(CO_2)_t = {} & \beta'_0 + \sum_{k=1}^{p} \beta'_1 \Delta\ln(CO_2)_{t-k} + \sum_{k=0}^{p} \beta'_2 \Delta\ln Y_{t-k} \\ & + \sum_{k=0}^{p} \beta'_3 \Delta\ln G_{t-k} + \sum_{k=0}^{p} \beta'_4 \Delta E_{t-k} + \lambda_1 \ln(CO_2)_{t-1} \\ & + \lambda_2 \ln Y_{t-1} + \lambda_3 \ln G_{t-1} + \lambda_4 E_{t-1} + \eta_t \quad (2)\end{aligned}$$

Recall that the objective of this paper is to examine both the short- and long-run relationships between CO_2 emissions and its major determinants. Eq. (2) is very well suited to deal with this purpose. In Eq. (2), for example, the long-run (cointegration) relationship is represented by the coefficients of λ_s, whereas the short-run dynamics is determined by the coefficients of the summation signs (Σ). Hence, Eq. (2) is called an error-correction representation of ARDL model.

The first step of the ARDL approach is to test the existence of the long-run relationship among the variables. For this, the null hypothesis of no cointegration ($H_0: \lambda_1 = \lambda_2 = \lambda_3 = \lambda_4 = 0$) is tested using an F-test. The computed F-statistic is then compared with two sets of critical values – upper and lower critical values - provided by Pesaran et al. (2001). If the computed F-statistic lies above (below) the upper (lower) critical value, the null hypothesis can (cannot) be rejected, indicating the (no) existence of the long-run relationship. In the second step, the selected ARDL model determined by model selection criteria is used to estimate the short- and long-run models.

3. Data

We estimate Eq. (2) using annual data from the U.S. over the 1967 to 2008 period. The data span has been chosen based on availability of the data for all the series. CO_2 emissions (measured in metric tons per capita) and energy consumption (measured in kg of oil equivalent per capita) are collected from the World Development Indicators (WDI) provided by the Work Bank. Per capita real GDP (2005 = 100) is used as a proxy for U.S. income and is taken from the Penn World Table (PWT 7.1) compiled by the University of Pennsylvania. Finally, following previous studies (e.g., Torras and Boyce, 1998; Heerink et al., 2001), the GINI coefficient is used as a proxy for income inequality and is obtained from the U.S. Census Bureau. It ranges from zero (perfect equality) to one (all income received by one individual). Finally, since all variables are transformed to natural logarithms, the estimated coefficients could be interpreted as elasticities.

4. Empirical results

The main advantage of the ARDL modeling is that this approach is applicable irrespective of whether the variables are $I(0)$ or $I(1)$ and hence avoids the pre-testing problem associated with unit root tests (Pesaran et al., 2001). However, the ARDL cannot be applied to $I(2)$ variables because the computed F-statistics are not valid in the presence of $I(2)$ variables (Ouattara, 2004). For this reason, the first requirement for the use of the ARDL is that none of the variables is $I(2)$ or beyond. The presence of a unit root in the variables is tested using an augmented Dickey–Fuller (ADF) test and the more recent Kwiatkowski–Phillips–Schmidt–Shin (KPSS) test. The results show that, for the level series, the ADF and KPSS tests seem to provide slightly different results (Table 1). The energy consumption (income), for example, is found to be nonstationary (stationary) with the ADF test, but stationary (nonstationary) with the KPSS test. For the first-differenced series, however, the results of both tests indicate that all the variables are stationary. This suggests that the four variables are $I(0)$ and/or

Table 1
Results of unit root tests.

Variable	ADF test		KPSS test	
	Level	First difference	Level	First difference
$\ln(CO_2)_t$	−2.80 (1)	−4.53** (1)	0.641** (9)	0.146 (9)
$\ln Y_t$	−3.23* (5)	−4.16** (1)	0.693** (9)	0.182 (9)
$\ln G_t$	−1.38 (2)	−6.09** (1)	0.685** (9)	0.211 (9)
$\ln EN_t$	−2.81 (1)	−4.22** (1)	0.156 (9)	0.143 (9)

The 10% and 5% critical values for the ADF (KPSS) are −3.20 (0.347) and −3.55 (0.463), respectively. Parentheses are lag lengths. The lag lengths for the KPSS tests are chosen by Schwert criterion.

* Denote rejection of the null hypotheses (nonstationarity for the ADF and stationarity for the KPSS) at the 10%.

** Denote rejection of the null hypotheses (nonstationarity for the ADF and stationarity for the KPSS) at the 5% levels.

[1] Researchers have vigorously debated the link between global warming and emission of greenhouse gases (GHG). Since carbon dioxide (CO_2) emissions are considered to be the primary GHG responsible for global warming, CO_2 has been the most widely used indicator in the recent EKC literature.

$I(1)$ variables and none of them are $I(2)$; hence, the ARDL modeling can be pursued on them.

As discussed earlier, the ARDL starts with the F-test to identify if the selected variables are cointegrated. Because the F-test is sensitive to the number of lags on each first-differenced variable in Eq. (2), we determine the optimal lag length based on the Akaike Information Criteria (AIC); setting the maximum five lags, for example, three is found to be the optimal lag length. With three lags, the calculated F-statistic is then found to be 4.31, which lies above the upper critical value of 3.77 at the 10% level, thereby rejecting the null hypothesis of no cointegration; hence, this suggests the existence of a stable long-run relationship among the selected variables. It is important to note that, since the critical values tabulated by Pesaran et al. (2001) are generated based on large sample sizes (e.g., 500 and 1000 observations), they may not be valid for small sample sizes like our sample of 42 annual observations, thereby raising questions about the validity of the results. To address this problem, Narayan. (2005) provides new (higher) critical values for sample sizes ranging from 30 to 80 observations. In our case, for example, the upper level of 10% critical value provided by Narayan. (2005) is 4.02, which is much higher than the corresponding critical value for Pesaran et al. (2001). This also leads us to reject the null of no cointegration, providing sufficient evidence that there is a long-run relationship among the four variables. Hence, our F-tests are shown to be robust even in small samples.[2]

In the second step, we use the selected ARDL model to estimate the long- and short-run coefficients. The long- and short-run results are summarized in Tables 2 and 3. First of all, one of our interests is the relationship between CO_2 emissions and per capita income. The estimated coefficients on the income are found to be negative and statistically significant at the 5% level in both the long- and short-run; for example, a 1% increase in per capita income leads to a decrease in per capita CO_2 emissions by approximately 0.35% (0.23%) in the long-run (short-run). It should be noted that a quadratic term in per capita income ($(\ln Y_t)^2$) is also included in Eq. (2) in order to directly examine the existence of the EKC hypothesis as previous studies did. The short- and long-run coefficients of the quadratic terms, however, are found to be statistically insignificant even at the 10% level; hence, they are excluded from the final model. These findings indicate a *monotonic* decrease in the relationship between CO_2 emissions and income in the United States. This can thus be interpreted to mean that the U.S. may have already moved beyond the EKC threshold level of income and hence CO_2 emissions decline with income growth; indeed, Fig. 1 shows that the U.S. already crossed the EKC turning point of approximately $20,000 per capita income around 1973.

Our central interest is the coefficient on income inequality. The estimates are positive for both the long- and short-run and statistically significant at the 5% level, indicating that a low Gini coefficient (greater income equality) decreases CO_2 emissions. This can thus be interpreted to provide evidence to support the *political economy argument*; that is, a more equal distribution of power and income in the U.S. over the past four decades has increased U.S. citizens' demand for a clean environment and the induced policy response, which in turn has led to more stringent environmental standards and stricter enforcement of environmental laws, thereby enhancing environmental quality. Finally, the long- and short-run coefficients on energy consumption are found to be positive and statistically significant at the 5% level. This suggests that CO_2 emissions tend to increase as U.S. energy consumption increases with income growth; for example, a 1% increase in per capita consumption of energy results in a rise in CO_2 emissions by approximately 1.05% (1.06%) in the long-run (short-run). Notice that the error-correction term (ec_{t-1}) is found to be negative and highly significant (Table 3), confirming evidence of the existence of cointegration relationship among the selected variables.

Finally, we conduct several diagnostic and stability tests in order to ascertain the goodness of fit of the ARDL model.

Table 2
Long-run coefficient estimates.

Variable	Coefficient
$\ln Y_t$	-0.35^{**} (-6.41)
$\ln G_t$	0.76^{**} (3.71)
$\ln EN_t$	1.05^{**} (12.25)
Constant	-2.16^{**} (-2.36)

*Denote significance at the 10%. Parentheses are t-statistics.

** Denote significance at the 5% levels.

Table 3
Short-run coefficient estimates and diagnostic tests.

Variable	Coefficient
$\Delta \ln Y_t$	-0.23^{**} (-5.16)
$\Delta \ln G_t$	0.49^{**} (3.81)
$\Delta \ln EN_t$	1.06^{**} (13.83)
ec_{t-1}	-0.64^{**} (-5.35)
Serial correlation	0.49 [0.48]
Functional form	1.08 [0.30]
Heteroskedasticity	1.35 [0.51]
Normality	1.11 [0.29]

*Denote significance at the 10% levels.
Parentheses are t-statistics. Brackets are p-values. ec_{t-1} is an error-correction term. Serial correlation of the residual is examined using the Lagrange-Multiplier (LM) test. Functional form is tested using the Ramsey's RESET test. Heteroskedasticity is tested with the LM test.

** Denote significance at the 5% levels.

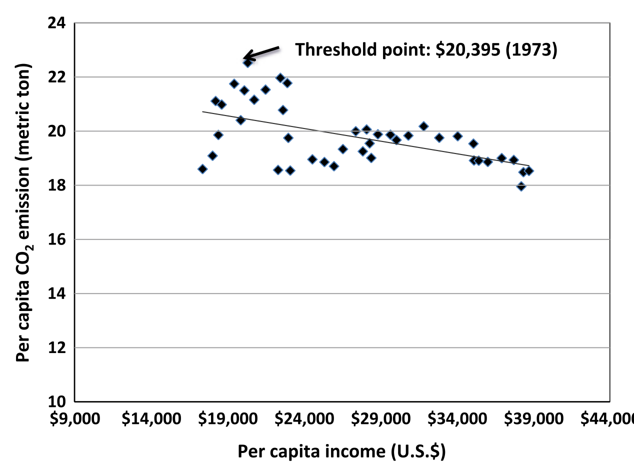

Fig. 1. Per capita CO_2 emissions and per capita income in the U.S.

[2] Additionally, Hakkio and Rush (1991) show that the power of a cointegration test relies more on the span of the data than on the sample size. For this reason, increasing sample size, particularly by using monthly or quarterly data, does not improve any robustness of cointegration analysis. From this, our dataset covering the 1967–2008 period are regarded as long enough to reflect the long-run relationship among the variables. Combined with the use of small-sample critical values, this should somehow mitigate our concern with the relatively small sample size and strengthen the credibility of our findings.

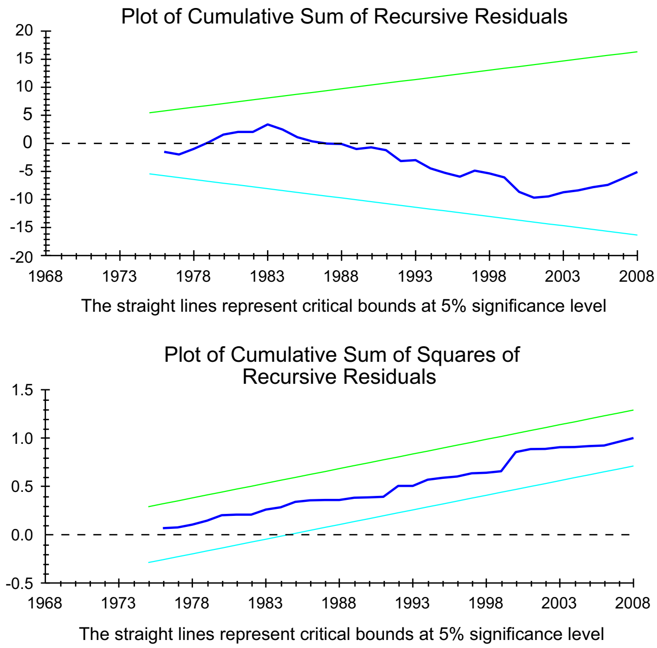

Fig. 2. Plots of stability tests.

Diagnostic tests on the short-run model as a system show no serious problems with serial correlation, heteroskedasticity, normality and functional form specification (Table 3). Additionally, the cumulative sum (CUSUM) and cumulative sum of squares (CUSUMSQ) tests are used to test for structural stability of our model (Fig. 2). The result shows that the estimated coefficients are generally stable over the sample period. Overall, therefore, the ARDL model presented above is well defined and provides sound findings.

5. Concluding remarks

The objective of this study is to examine the growth-inequality-environment nexus. Although several empirical studies on this issue exist, relatively little attention has been paid to the dynamic effects of income equality, income and other relevant variables on the environment in the framework of country-specific time series data. Therefore, the primary contribution of this study is to assess the short- and long-run effects of income inequality, per capita real income and energy consumption on CO_2 emissions in the U.S. using an autoregressive distributed lag (ARDL) approach to cointegration. The results show that income inequality and CO_2 emissions have a positive relationship in both the long- and short-run, suggesting that greater equality of income in the U.S. has a beneficial effect on environmental quality. This finding is consistent with the results of Torras and Boyce (1998) and Magnani (2000). However, this contrasts with Heerink et al. (2001) who find that greater equality of income has a detrimental effect on the environment. We also find that income has a significant negative relationship with CO_2 emissions in the short- and long-run, indicating that economic growth in the U.S. enhances environmental quality. Finally, it is found that energy consumption has a detrimental effect on the environment in both the short- and long-run.

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