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The European Climate Policy is Ambitious: Myth or Reality?

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The European Climate Policy is Ambitious: Myth or Reality?

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Abstract

We investigate carbon emission trends among EU Member States by testing the assumption of β-type convergence in per capita CO_2 emissions, conditional upon per capita output, world oil price, energy use per capita and investment in renewable energy. Our study supports the assumption of conditional convergence among all EU Member States. It should take around 10 years for the EU-15 countries to stabilize their per capita emissions. This result holds if we include the new Member States in the sample. We also find that the emission growth/income relation is strictly negative, indicating that EU-15 countries switched to a less carbon intensive economy starting from the early 1990s. This result remains robust when the new Member States are included. We therefore argue that the decline in EU carbon emissions is a long-term trend and not a result of the economic crisis. We then discuss the effectiveness of climate and energy policies and the EU burden-sharing agreement. Some countries like Germany, Great Britain and France can meet their carbon targets without adopting more aggressive climate and energy policies by 2020. Other EU-15 Member States can reduce their domestic emissions beyond their targets if they adopt energy-efficient technologies. Most of the new Member States emit much less than their domestic targets even when per capita income and oil price increase.

Keywords: Convergence, Dynamic Panel Data Models, Carbon Dioxide, European Union Climate Policy.
JEL Codes: Q42, Q48

Abstract

Nous analysons les évolutions dans le long terme des émissions de carbone en Europe en s'appuyant sur le concept de convergence des émissions de CO_2 par tête conditionnelle au revenu par tête, au prix mondial du pétrole, à la consommation énergétique par tête et à l'investissement en énergie renouvelable. L'hypthèse de convergence conditionnelle entre les pays de l'Union Européenne est vérifiée. Les pays de l'UE-15 devraient stabiliser leurs émissions d'ici 10 ans. Ce résultat est inchangé si nous incluons les nouveaux pays Membres dans l'échantilllon. Les économies de l'Union Européenne sont peu intensives en carbone, i.e., la relation croissance des émissions/revenu est strictement négative. Ce résultat est robuste si nous incluons les nouveaux Etats Membres. Puis, nous discutons de l'efficacité des politiques énergétique et climatique et de la répartition de l'effort d'abattement entre les différents pays Membres. L'Allemagne, la Grande-Bretagne et la France peuvent atteindre leur cible de carbone sans réaliser d'efforts supplémentaires. Les autres Etats Membres de l'UE-15 peuvent atteindre la cible en réalisant des investissements dans les énergies renouvelables et en améliorant leur efficacité énergétique. Les émissions des nouveaux Etats Membres devraient être inférieures à leur valeur cible malgré l'augmentation du revenu par tête et du prix de pétrole.

Mots-clés : Convergence, Modèle de Panel Dynamique, Dioxyde de Carbone, Politique Climatique Européenne.
Codes JEL : Q42, Q48

1 Introduction

The former European Commission president, Jose Manuel Barroso, recently declared that "*No player in the world is as ambitious as the EU when it comes to cutting greenhouse gas emissions*". The European Union (EU) was the only region of the Annex I countries to achieve its Kyoto target. In 2008-2012, total greenhouse gas (GHG) emissions were 10.6% below their 1990 levels while the Kyoto Protocol had imposed a reduction of only 8%.[1] Some argue that this good performance is the result of the financial and economic crisis. However, it is worth noting that most of the EU countries were in track to meet their Kyoto targets in 2004-2008 (Eboli and Davide, 2012). In 2009, despite a slow down in international negotiations, the European Commission decided to embark in new commitments by defining three objectives for 2020: a 20% GHG emissions reduction below their 1990 levels, an increase in the share of renewable energy source over total energy production to at least 20%, and a 20% increase in energy efficiency.[2] In October 2014, the Commission sought to reinforce its drive for a low carbon economy by setting new targets for 2030, including a reduction in domestic GHG emissions by 40% below the 1990 levels, an increase in the share of renewable sources in the production of energy to 27% and a rise in energy efficiency by 27%. In this context, the role being played by the EU is quite unique and raises some questions: i) is this carbon emission reduction a long-term trend, i.e., has the EU economy already switched to a low carbon economy? ii) if so, are the carbon emissions targets set by the EU ambitious enough, or possibly too ambitious? A detailed examination of the long-term carbon emissions trends across the EU Member States is required to address these issues.

To investigate long-term carbon emission trends, we apply the econometric framework based on the Solow's model, which is used in the macroeconomic literature on income conver-

[1]This good result hides substantial differences between Member States. Sweden, Germany, and France succeeded in meeting their emissions reduction targets while Luxembourg and Austria failed to do so. However, the largest decrease in carbon emissions occurred in the new Member States although they only signed a voluntary agreement in 2004 when they joined the EU (except Cyprus and Malta). EU carbon emissions decreased by around 15% below their 1990 levels.

[2]The generic definition of energy efficiency is "a way of managing and restraining the growth in energy consumption. Something is more energy efficient if it delivers more services for the same energy input, or the same services for less energy input" (IEA, 2013). According to the Energy Efficiency Directive, EU Member States are supposed to increase their energy efficiency by 20%, e.g., to reduce their primary energy consumption by 20% (page 2, Directive 2012 (2012)). In the rest of the paper, we refer to energy efficiency as the decrease in primary energy consumption.

gence (Baumol (1986), Barro and Sala-i Martin (1992) and Quah (1996)).[3] Its key prediction is that per capita income among economies should converge if economic characteristics such as savings rate or technological progress rate are controlled. This framework has been extended to explain pollution emissions across different countries (Brock and Taylor, 2010). Numerous studies have tested the hypothesis of convergence in pollution among different regions or countries. In a seminal paper, Strazicich and List (2003) test the convergence of per capita CO_2 emissions among 21 industrialized countries between 1960 and 1997. Using annual data and employing two econometric methodologies (cross-sectional approach and unit root test), they show that per capita CO_2 emissions have converged. Ordás Criado et al. (2011) extend the Ramsey Model to endogenous carbon emissions reduction. Their empirical results confirm the existence of a defensive effect (growth rate of per capita emissions is negatively related to the initial level of per capita emissions) and a scale effect (growth rate of per capita emissions is positively related to the growth rate of per capita output) for two pollutants (sulfur oxides and nitrogen oxides) in 25 European countries over the period 1980-2005. Ordás Criado and Grether (2011) examine cross-country convergence process for per capita CO_2 emissions with a panel of 166 world areas spanning the years 1980-2005. Based on non-parametric methodologies, they identify clusters of converging economies. Europe, Central Asia, Sub-Saharan Africa and the low-income countries converge toward lower per capita emissions in the long run, while those for OECD, EU-15 and the G20 are close to their current distribution. Jobert et al. (2010) investigate the convergence hypothesis in 22 European countries over the period 1971-2006. By using Bayesian shrinkage method, their results support the assumption of absolute convergence in per capita CO_2 emissions. Since countries differ in both their speed and volatility of convergence in emissions, different groups of countries having different emissions characteristics can be identified.[4]

[3] See Durlauf et al. (2005) for a review of the literature.

[4] The first group, called "volatile polluters", is characterized by a high speed of convergence and their emission levels show a high variation in time. This group is mainly composed of Northern European countries. The second group, qualified as "ecologists", is composed of Eastern countries and three EU-15 countries (France, Germany, Ireland). Their initial level of per capita emissions is high, but, they show a decreasing trend in per capita CO_2 emissions especially after 1990. South European countries (except Portugal) belong to the third group named "Club Med Polluters". They show a low initial emission level, but an increasing trend for this variable. Finally, Portugal and Turkey form the fourth group. They are characterized by a low convergence process and their carbon emissions increase sharply.

In the first step of our analysis, we test the assumption of convergence in per capita emissions among the 15 Member Sates of the European Union (i.e., the historical Member States) conditional on their level of per capita income, world oil price and energy use per capita using a dynamic panel data set over the period 1960-2009. Our results confirm that the per capita emissions have conditionally converged and that the EU-15 countries should stabilize their per capita emissions in roughly 10 years, i.e., around 2020/2024. This framework also allows us to examine whether the historical Member States have switched to a low carbon economy by testing the existence of a structural break in the relation between emission growth and per capita income. Before the 1990s, an inverted U-shaped exists. After the 1990s, the emission growth/GDP per capita relationship is strictly negative. In a second step, we explore the process of convergence in per capita emissions conditional on their level of per capita income, world oil price, energy use per capita and investment in renewable sources among all EU members (EU-15 countries and new Member States) over the period 1990-2009.[5] The speed of convergence is robust to the inclusion of the new Member States, i.e., all EU Member States should stabilize their per capita emissions in about 10 years. In addition, for all Member States a higher level of GDP per capita leads to a decrease in emission growth although this effect is *limited*. A change in oil price should have a low impact on emission growth, while investment in renewable technologies or improvement in energy efficiency can slow down emission growth. The main contribution of this paper is to use our regression results to investigate the effectiveness of the EU energy and climate policies by employing bootstrap method. This allows us to identify: i)the extent to which the EU members may achieve their domestic carbon emissions reduction target by 2020 and ii)the main drivers (macroeconomic variables or climate and energy policies) that could affect the efforts EU members must make to achieve their 2020-targets. Our results show that Great-Britain, Germany and France will reach their carbon target without additional investment in renewable energy or improvement in energy efficiency around 2020. Other Member States should invest more in renewable energy or in energy efficiency to reach their 2020-commitment. For instance, Luxemburg and Sweden should increase their production of renewable energy by at least 20%. However, improved

[5] In the rest of the paper, we name indifferently the EU-15 countries as the historical Member States or EU-15. The countries that joined the European Union after 2004 are named the new Member States.

energy efficiency appears to be a better climate policy lever. With the exception of Ireland and Finland, all of the EU-15 Member States can hit their domestic targets by investing in more energy efficient technologies. However, most of the Eastern European countries are already emitting less than their targets level, and will honor their 2020-commitments even if per capita income or oil price increase.

The rest of the paper proceeds as follows. Section 2 presents the European energy and climate policies. Section 3 describes our econometric methodology and data. Results are discussed in section 4. Finally, section 5 concludes.

2 Policy background

In this section, we discuss the European Union energy and climate policies since the end of the Second World War.

The achievements of the EU energy and climate policies

The history of the European Union is rooted in energy issues (Keppler, 2007). The Treaty establishing the European Coal and Steel Community (ECSC) was signed in 1951. It set up a common customs union for two commodities (coal and steel) which was essential for warfare and reconstruction alike. Six years later, the European Atomic Energy Community (EURATOM) was established to extend the power of the ECSC to other sources of energy and in particular nuclear power. The first oil crisis highlighted the need to ensure energy security. In 1974, the European Council adopted a program to diversify energy sources. Later, in 1995, the EU attempted to liberalize the energy market to promote competition and the security of supply. In the late 1990s, EU energy policy began to focus on climate change in addition to improving energy security. In 1997, under the Kyoto Protocol, the EU-15 agreed to reduce its GHG emissions by 8% below their 1990 levels over the period 2008-2012. Specific targets were defined for each Member States based on their energy mix and economic performance. Countries where the share of fossil fuel in the energy was high such as Luxembourg, Germany and Austria had to substantially reduce their carbon emissions. Countries like Finland and

France where the share of nuclear power in the production of electricity already was high, had to stabilize their carbon emissions. Countries with lower per capita GDP like Spain, Greece and Portugal could increase their carbon emissions. To meet the overall 8% reduction target, two key Directives on Renewable Energy were established. The 2001 Directive quantified an overall target for electricity produced from renewable energy.[6] The 2003 Directive reinforced these objectives by establishing a mandate on biofuel use, minimum taxation rates for energy products, electricity and heating fuels. The most important policy tool was the creation of the carbon exchange trading market in 2005 which is often considered as the centerpiece of the EU's climate policy.

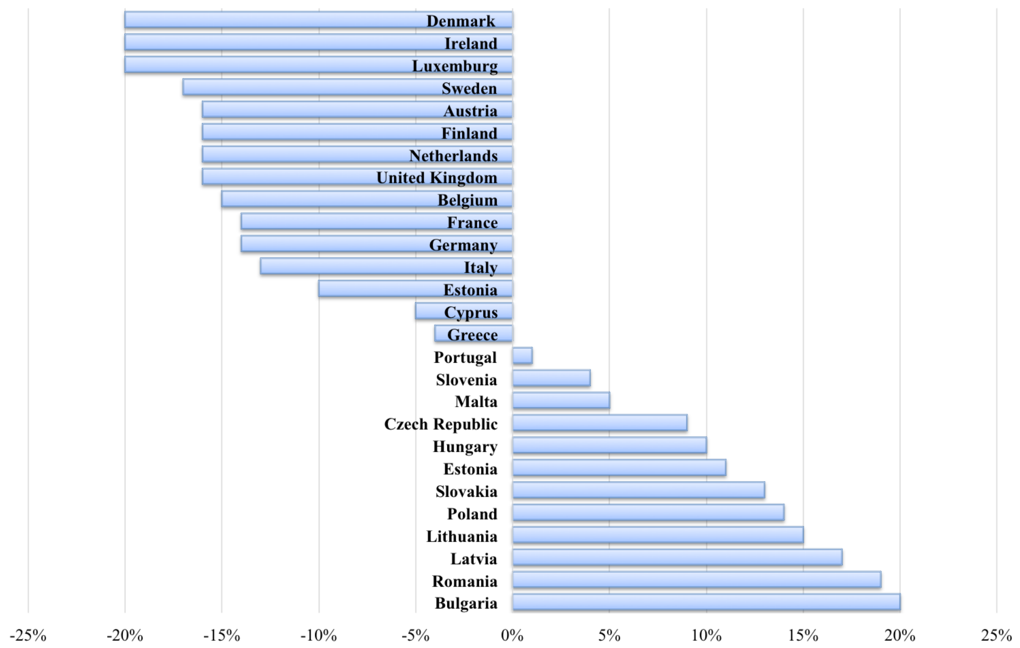
The challenges of the EU energy and climate policies

To prepare an EU climate policy after the end of the Kyoto Protocol, the European Commission defined new and ambitious commitments for carbon emissions reductions in 2007. Quantifiable targets, the so-called 20/20/20, were set up: a reduction in EU GHG emissions of at least 20% below 1990 levels; 20% of EU energy production to come from renewable resources and a 20% reduction in primary energy use, to be achieved by improving energy efficiency. The overall target on carbon emissions was translated into national targets which took into account the per capita income and energy mix of each Member State (see figure 1). Historical Member States must make greater efforts to reduce their carbon emissions while the emissions of the new Member States can increase them. The EU is on track to meet its overall renewable energy target since the share of renewable energy in gross final energy production rises from around 8% in 2004 to 12% in 2010 and to over 14% in 2014 (EUROSTAT, 2013). In contrast, much work remains to be done in terms of energy efficiency. Primary energy use increased by around 12% from 1990 to 2009 in the EU. This number hides significant disparities. Figure 2 shows the growth rates of primary energy use from 1990 to 2009 for each EU Member State. The largest declines in the primary energy use occurred in Eastern European countries while the largest increases occurred in the historical Member States. After 1990, drastic reductions in

[6] The Directive set an overall target of 22% of electricity produced from renewable by 2010. Specific national targets were defined based on the energy mix of each country.

carbon emissions have been observed for the new Member States. For instance, energy use per capita decreased by 20% in Romania. Zugravu et al. (2010) identify several factors to explain this tremendous drop, including a decrease in industry's share of GDP, investments in clean technologies and the political institutions. In October 2014, the European Commission defined ambitious targets for 2030 like the reduction of domestic carbon emissions, the increase in the share of renewable sources in the total production of energy and the improvement in energy efficiency (European Council, 2014).

Figure 1: CO_2 emissions reduction targets for EU Member States by 2020 (expressed in percentage change in 2020 compared to 1990 levels)

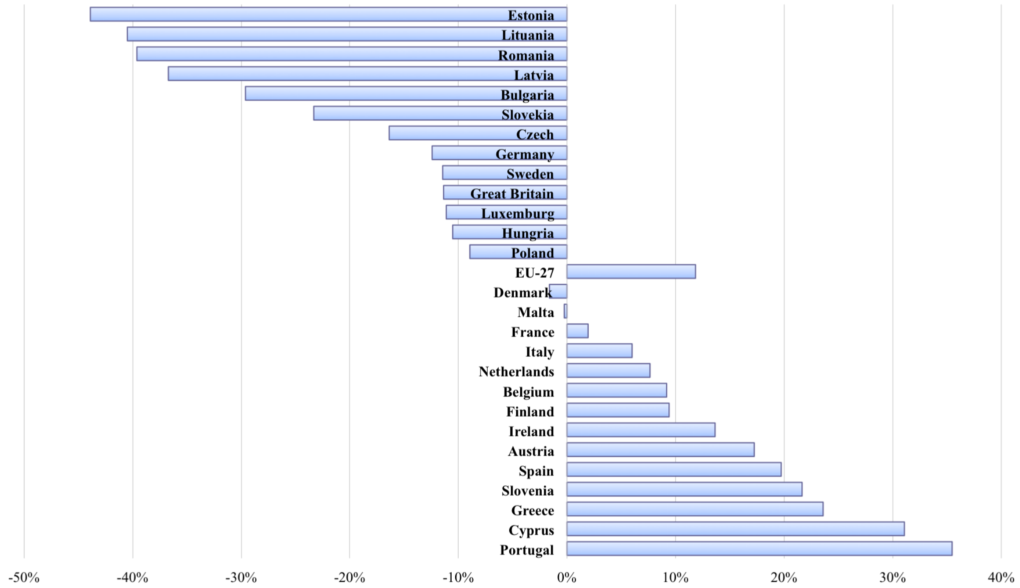


Source: EEA (2013b), page 102; *Notes*: The emissions reduction targets were established in 2007 by the European Commission based on the economic development and energy mix of each EU Member State.

3 Econometric strategy and data

Before defining our econometric strategy and the data we use, we analyze graphically the process of absolute convergence in per capita emissions among the EU Member States. According to this concept, the countries with lower per capita emissions levels are expected to experience higher growth rates of pollution. Hence, they may catch-up with the most polluting countries.

Figure 2: Percentage change in energy use per capita for EU Member States from 1990 to 2009

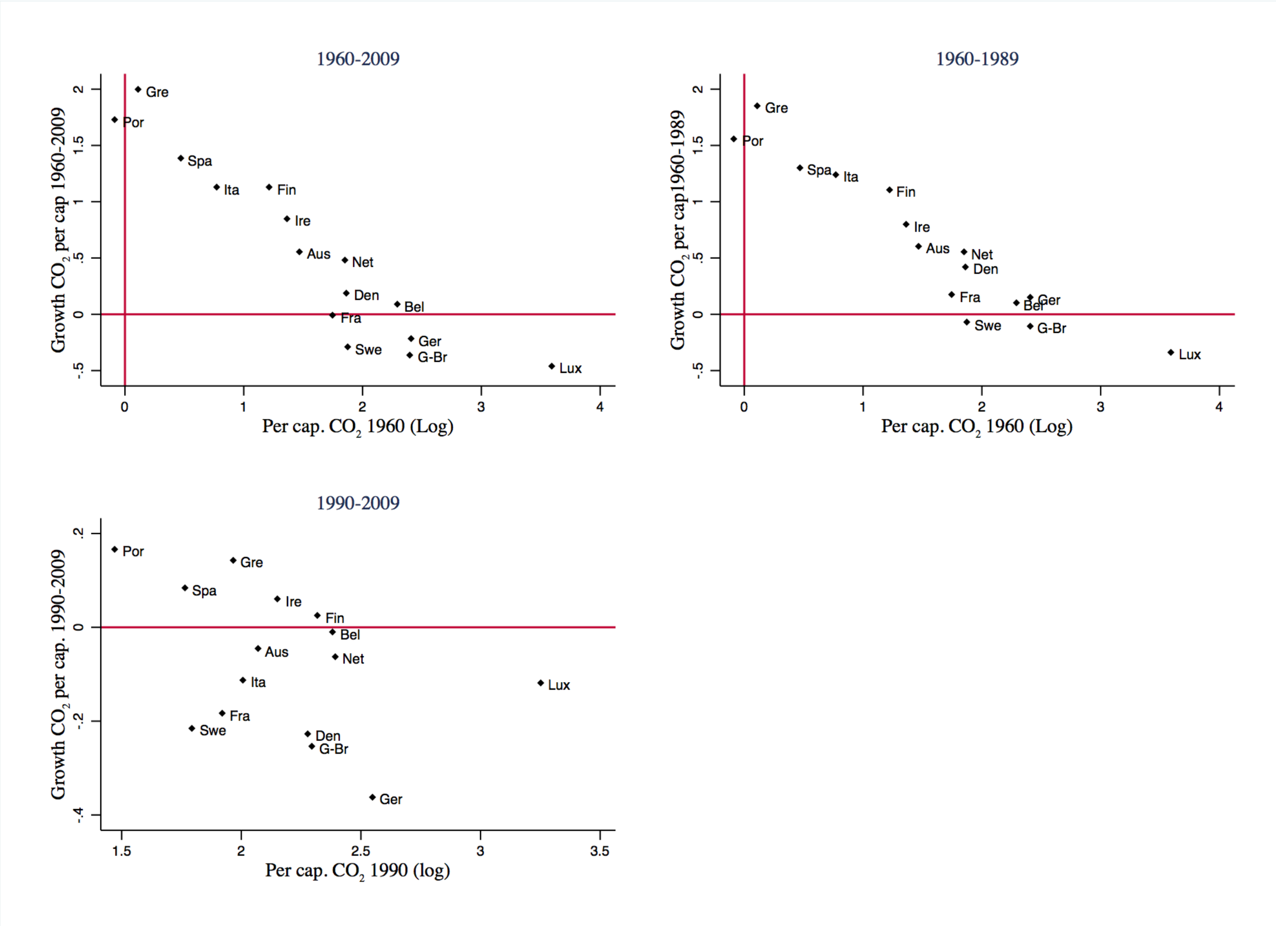


Source: EUROSTAT (2013), *Notes*: EUROSTAT (2013) defines the primary energy consumption as the Gross Inland Consumption excluding all non-energy use of energy carriers (e.g. natural gas used not for combustion but for producing chemicals). This quantity is relevant for measuring the true energy consumption and for comparing it to the 2020 targets.

Preliminary data analysis

To examine the potential impact of EU energy and climate policies on the carbon emissions trends from the early 1960s, we analyze the convergence in per capita CO_2 emissions among the EU-15 countries. Figure 3 shows the absolute convergence in per capita emissions for each EU-15 country over three periods: 1960-2009 (figure on the top left), 1960-1989 (figure on the top right) and the 1990-2009 (figure on the bottom left). We split the sample into two sub-periods: 1960-1989 and 1990-2009 because many countries adopted environmental policies in the early 1990s. We can clearly see that from 1960 to 2009, the less polluting countries in 1960 (Greece and Portugal) experienced the highest growth rates of per capita emissions. A group of countries located in the bottom-right below the horizontal black line is formed by Luxembourg, Germany, Sweden and France. They exhibit a negative emission growth. Before the 1990s, only Sweden and Great-Britain have a negative per capita emission growth rate. After the 1990s, the growth rates of per capita emissions are negative for most of the EU-15 countries. Only Portugal, Greece, Ireland and Finland show an increasing trend. However, the differences in per capita CO_2 emission growth rates are much lower over the second period than over the first one. The data analysis over the whole period seems to reveal that the EU economy switched to a low carbon economy before the implementation of the EU climate policies in 2001.

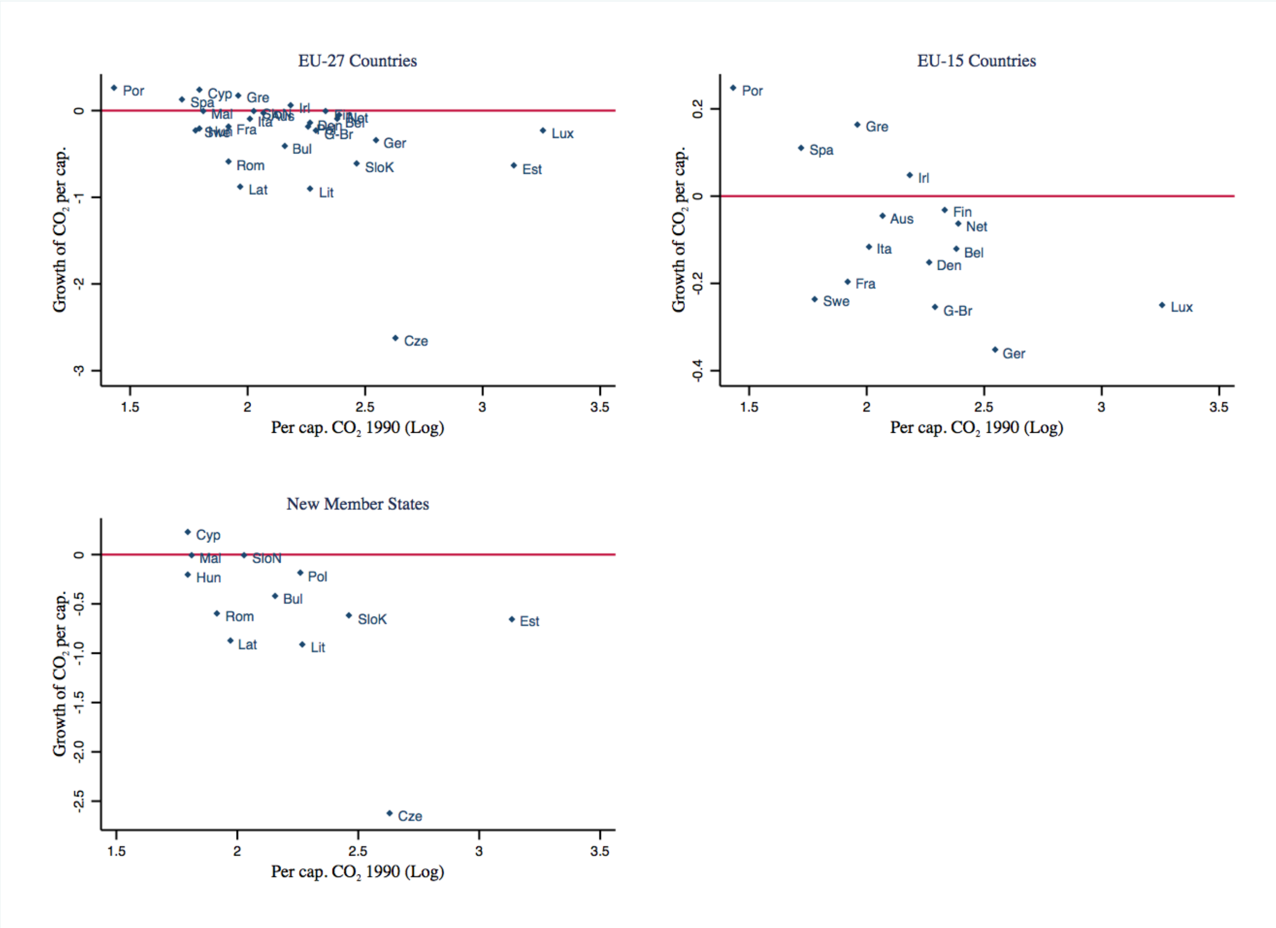
Figure 3: CO_2 emission growth (1960-2009) versus initial per capita CO_2 emissions (1960) for EU-15 countries



Source: Per capita carbon emissions are from World Bank (World Bank, 2013). *Notes*: Growth of CO_2 emissions per capita is the average annual growth rate of CO_2 emissions per capita over the period. We use the following abbreviations: Aus: Austria; Bel: Belgium; Den: Denmark; Fin: Finland; Fra: France; Ger: Germany; G-Br: Great-Britain; Gre: Greece; Ire: Ireland; Ita: Italy; Lux: Luxemburg; Net: The Netherlands; Por: Portugal; Spa: Spain; Swe: Sweden.

Then, we include the New Member States to our sample since they are committed to reduce their emissions by 2020. Figure 4 shows the absolute convergence in per capita emissions for all Member States (figure on the top left), EU-15 countries (figure on the top right) and new Member States (figure on the bottom left). Although the new Member States have different country characteristics from the historical Member States, their per capita emissions in 1990 do not differ substantially from those of the latter. More surprisingly, we clearly notice that the new Member States exhibit the highest decrease in carbon emissions. The average rate of decrease in per capita emissions among the historical Members does not exceed 0.5% while it reaches 1.5% among the new Member States.

Figure 4: CO_2 emission growth (1990-2009) versus initial per capita CO_2 emissions (1990) for all member States

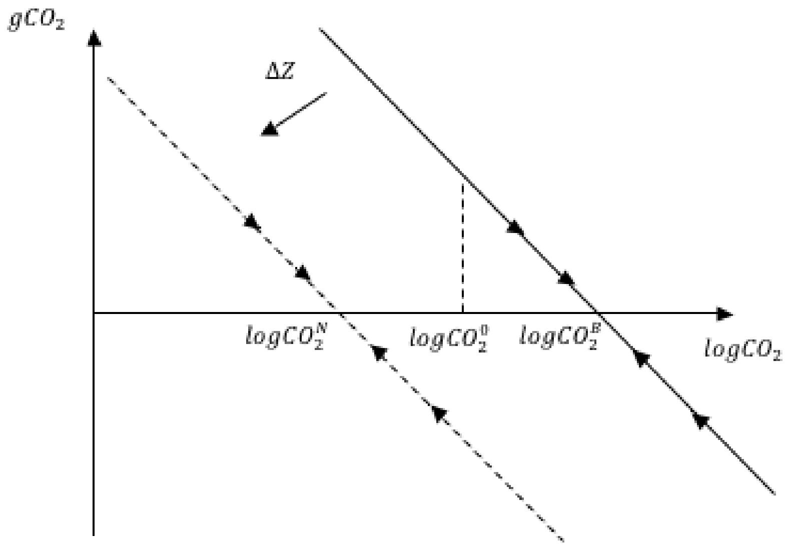


Source: Per capita carbon emissions are from World Bank (World Bank, 2013). *Notes*: Growth of CO_2 emissions per capita is the average annual growth rate of CO_2 emissions per capita over the period. We use the following abbreviations: Aus: Austria; Bel: Belgium; Den: Denmark; Fin: Finland; Fra: France; Ger: Germany; G-Br: Great-Britain; Gre: Greece; Ire: Ireland; Ita: Italy; Lux: Luxemburg; Net: The Netherlands; Por: Portugal; Spa: Spain; Swe: Sweden; Bul: Bulgaria; Cyp: Cyprus; Cze: Czech Republic; Est: Estonia; Hun: Hungary; Lat: Latvia; Lit: Lithuania; Mal: Malta; Pol: Poland; Rom: Romania; SloK: Slovakia; SloN: Slovenia.

Preliminary data analysis suggests that two trends may exist. The first is that the decrease in carbon emissions observed in the EU may be a long term process. The second is that the economic growth in the new Member States has not generated high emission growth. To test the existence of these trends, we borrow our econometric strategy from β-convergence in income (Durlauf et al., 2005). This literature has been enriched to analyze the process of

β-convergence in per capita emissions conditional on country specific characteristics. Figure 5 illustrates the convergence process. As we can see on figure 5, the emission growth (gCO_2) is a declining function of the initial level of carbon emissions ($logCO_2^0$). Per capita emissions should converge to $logCO_2^B$, we call this value the asymptotic value of carbon emissions. However, this value may shift with country-specific characteristics and climate and energy policies. For instance, we can expect that climate and energy policies, represented by ΔZ on figure 5, can cause a decrease in the asymptotic value of per capita emissions and a shift to the new asymptotic value of carbon emissions $logCO_2^N$.

Figure 5: β-convergence in per capita CO_2 emissions conditional on country-specific characteristics



Note: We assume that ΔZ represents climate and energy policies.

Econometric strategy

As in Ordás Criado et al. (2011), we construct a panel data based on five-year periods (T = 5) to capture long-term adjustments. A critical step in the analysis of the β-convergence is the choice of the vector of control variables since the latter are supposed to allow for country differences in the time path of emissions (see figure 5). Many suggestions can be found in the literature, for example, GDP per capita, energy prices, climate, industry's share in GDP.[7] In

[7] Strazicich and List (2003) chose four control variables (GDP per capita, price of gasoline, population density and average temperature) to test the conditional convergence in 21 industrialized countries. To test the conditional convergence among 22 European States, Jobert et al. (2010) included three control variables:

our study, we include four control variables to analyze the impact of macroeconomic shocks and climate and energy policies on the convergence process and the asymptotic value of carbon emissions. First, the GDP per capita is employed as a measure of the wealth of the country. As in Strazicich and List (2003), we assume that in the initial phase of the growth process, i.e., for *low* levels of per capita GDP, emission growth tends to rise, and that once the GDP per capita passes some threshold level, economic growth does not cause an increase in carbon emissions. To capture this possible inverted U-shaped relation, we introduce a quadratic term. We also introduce oil price which can be interpreted as a measure of fossil fuel price. Higher energy prices make alternative and carbon free energy like wind, solar more competitive. In the long run, they thus lead to lower rates of carbon emissions. The two remaining control variables: energy use per capita and growth in the production of renewable energy are introduced to capture the effects of the EU energy and climate policies on emission growth. Growth in the production of renewable sources is used as a proxy for investment in renewable sources. The generic equation of conditional convergence is:

$$\begin{aligned} gCO_{2_{i,t}} &= \gamma_i + \beta logCO_{2_{i,t-T}} + \alpha logGDP_{i,t} + \delta logGDP_{i,t}^2 \\ &+ \mu log(OilPrice)_t + \theta log\mathbf{Z_{i,t}} + \xi_{i,t} \end{aligned} \quad (1)$$

where $gCO_{2_{it}}$ is the annual average growth rate of carbon emissions, it is calculated as the average log changes $(1/T)log(CO_{2_{it}}/CO_{2_{i,t-T}})$ over the period t-T to t; $CO_{2_{i,t-T}}$ is the level of CO_2 per capita emissions at the beginning of the period t-T or the initial level of per capita emissions,[8] $GDP_{i,t}$ is the average GDP per capita in country i over the period t-T to t, $OilPrice_t$ is the average world oil price over the period t-T to t, $\mathbf{Z_{i,t}}$ is a vector of time-varying country characteristics like energy use per capita and growth rate of the production of renewable sources,[9] $\xi_{i,t}$ is the error term. We introduce country fixed-effect in order to take into account heterogeneity across countries. The hypothesis of β-convergence is supported if the coefficient β is significantly negative. The relation between per capita emission growth

the GDP per capita, country population and industry's share of GDP.

[8]In the rest of the paper, we will use the term initial level of the variable to refer to the value of this variable at the beginning of the period t-T.

[9]As for the other control variables, we calculate their average value over the period t-T to t. Data on the growth rate of renewable sources production are available after 1990.

and GDP per capita has inverted-U shape if α is significantly positive and δ is significantly negative. The turning point is obtained by: $-\frac{\alpha}{2\delta}$.

In the first step of our analysis, we focus on the β-convergence among the EU-15 countries with a panel set spanning 1960 to 2009.[10] To test if a structural break exists in the relation between per capita emission growth and GDP per capita, we introduce a dummy variable PER1 which takes the value 1 over the period 1960-1989 and 0 otherwise. The following equation is estimated:

$$\begin{aligned} gCO_{2_{i,t}} &= \gamma_i + \beta logCO_{2_{i,t-T}} + \alpha_1 logGDP_{i,t} + \alpha_2 logGDP_{i,t} * PER1 \\ &+ \delta_1 logGDP^2_{i,t} + \delta_2 logGDP^2_{i,t} * PER1 + \mu log(OilPrice)_t + \theta log\mathbf{Z_{i,t}} + \xi_{i,t} \quad (2) \end{aligned}$$

If α_2 and γ_2 are significantly different from zero, a structural break exists. Otherwise, no structural break exists.

In a second step, we extend our sample to all EU members by using a dynamic panel set covering the period 1990-2009.[11] The data set starts after 1990 since most of the new EU members emerged from the dissolution of the Union of Soviet Socialist Republics in 1991. Our aim is to detect a structural difference between the historical EU members and the new EU members. We introduce a dummy variable (NEU15) which takes the value 1 if the country i is a new EU members and 0 otherwise. The following equation is estimated:

$$\begin{aligned} gCO_{2_{i,t}} &= \tilde{\gamma_i} + \tilde{\beta} logCO_{2_{i,t-T}} + \tilde{\alpha_1} logGDP_{i,t} + \tilde{\alpha_2} logGDP_{i,t} * NEU15 \\ &+ \tilde{\delta_1} logGDP^2_{i,t} + \tilde{\delta_2} logGDP^2_{i,t} * NEU15 + \tilde{\mu} log(OilPrice)_t + \tilde{\theta} log\mathbf{Z_{i,t}} + \tilde{\xi_{i,t}} \quad (3) \end{aligned}$$

If $\tilde{\alpha_2}$, and $\tilde{\delta_2}$ are statistically different from zero, a structural difference exists between the two groups of countries. Otherwise, no structural difference exists.

We first estimate the dynamic panel equations: equation (2) and equation (3) with the Least Square Dummy Variable (LSDV); however, the estimator is biaised (Greene, 2012). Two estimation techniques exist to tackle with this problem. The first, GMM methods for dynamic

[10]This data set includes 10 periods of five years: 1960-1964; 1965-1969; 1970-1974; 1975-1979; 1980-1984; 1985-1989; 1990-1994; 1995-1999; 2000-2004; 2005-2009.

[11]This data set includes 4 five-year periods: 1990-1994; 1995-1999; 2000-2004; 2005-2009. In July 2013, Croatia joined the EU. However, we do not include this country in our data set since its carbon emissions represented less than 1% of EU emissions in 2010 (World Bank, 2013).

panels developed by Arellano and Bond (1991) and Arellano and Bover (1995) have been widely used in growth models. The second econometric method involves instrumental variable, and is what we use in this paper in the form of IV-GMM estimators (Checherita-Westphal and Rother, 2012). We prefer this second instrumental variable methodology since it allows us to estimate a fixed effects model which controls for non-observable country characteristics. It is crucial to estimate a fixed-effect model since our objective is to use the estimated coefficients of this equation to measure i) the efforts each Member States should make to reach their targets and ii) the potential role of climate and energy policies and macroeconomic shocks. We instrument the initial level of per capita emissions for each EU Member State through the initial energy use per capita.[12]

Data

To estimate equation (2) and equation (3), we build two data sets named respectively Panel A and Panel B. The World Bank (World Bank, 2013) provides a full data set on per capita carbon emissions measured in metric tons per capita from 1960 for each country of the world. According to the definition given by the World Bank, "carbon emissions are those stemming from the burning of fuels and the manufacture of cement. They include carbon dioxide produced during consumption of solid, liquid, and gas fuels and gas flaring".[13] Per capita Gross Domestic Product (GDP) is from the Penn World Table (Heston et al., 2012). It is deflated by country into 2005 US dollars and calculated in purchasing power parity. Oil price is from the World Bank (2014). It is calculated as the average spot price of Brent, Dubai and West Texas Intermediate and expressed in 2005 US dollars. According to EUROSTAT (2013), primary energy consumption means the Gross Inland Consumption excluding all non-energy use of energy carriers (e.g. natural gas used not for combustion but for producing chemicals). It is expressed in tons oil equivalent (or, toe). The growth rate of the production of renewable

[12]We tested different instruments for the initial level of per capita emissions like the savings rate and the population growth rate following economic growth theory (Brock and Taylor, 2010). The first stage test reveals that these instruments are weak. The results are available upon request.

[13]The data base omits carbon emissions caused by deforestation, land-use and land-use changes (LULUCF), and wood burning for energy; but suitable data on these measures are currently unavailable over the whole period. Other greenhouse gases like methane, nitrous oxide and fluorinated gases are emitted in smaller quantities than CO_2. The most important GHG is by far CO_2 which accounts for more than 80% of total EU emissions excluding LULUCF over the period 1990-2011. The proportion is similar for EU-15 (EEA, 2013a).

sources is calculated from EUROSTAT (2013), it is available only after 1990.

Table 1 below displays the summary statistics for the two panel data sets. Before the 1990s, emission growth in EU-15 countries was strictly positive while it became negative after the 1990s (see panel A, table 1). The examination of the carbon emission growth among all of the Member States reveals that historical Member States and new Member States both exhibit a negative emission growth despite their specific country characteristics like average GDP (See panel B, table 1). We must note that the new Member States exhibit lower energy use per capita and higher growth rates for production of renewable sources than the Historical Member States.

Table 1: Summary Statistics

	Full Period			*1960-1989*			*1990-2009*		
Panel A: EU-15, 1960-2009									
	Obs.	Mean	Std. Dev.	Obs.	Mean	Std. Dev.	Obs.	Mean	Std. Dev.
Dependent variable									
Growth of CO_2 per cap.(%)	150	1.00	3.10	90	1.90	3.37	60	-0.24	2.22
Explanatory variable									
Initial CO_2/cap (ton/cap)	150	9.46	6.32	90	9.43	7.50	60	9.50	4.02
Control variables									
GDP/cap (2005 US $/cap)	148	22,489	10,357	88	16,996	5,683	60	30,546	10,422
Oil price (2005 US$/barrel)	150	25	17	90	19	13	60	33	19
Energy use/cap (toe/cap)	150	3,678	2,089	90	3,326	2,286	60	4,207	1,634
Instrument									
Initial energy use/cap (toe/cap)	150	3,599	2,129	90	3,226	2,340	60	4,159	1,630
Panel B: EU, 1990-2009									
	EU			*EU-15*			*New Member States*		
	Obs.	Mean	Std. Dev.	Obs.	Mean	Std. Dev.	Obs.	Mean	Std. Dev.
Dependent variable									
Growth of CO_2 per cap. (%)	108	-0.93	3.15	60	-0.24	2.22	48	-1.79	3.80
Explanatory variable									
Initial CO_2/cap (ton/cap)	108	8.69	3.95	60	9.50	4.02	48	7.68	3.55
Control variables									
GDP/cap (2005 US $/cap)	108	22,677	12,196	60	30,546	10,422	48	12,841	4,941
Oil price (2005 US$/barrel)	108	33	19	60	33	19	48	33	19
Energy use/cap (toe/cap)	108	3,564	1,506	60	4,208	1,637	48	2,758	778
Growth renewable production (%)	108	4.18	3.92	60	3.50	3.71	48	4.90	4.10
Instrument									
Initial energy use/cap (toe/cap)	108	3,575	1,520	60	4,159	1,630	48	2,842	956

Source: Growth of CO_2 per cap. and Initial CO_2/cap: World Bank (2013); GDP/cap Heston et al. (2012); Energy use/cap and Growth renewable production: EUROSTAT (2013). Notes: Cap.emission growth is the average growth rate of per capita emissions over the five-year period; Initial cap. CO_2/cap is the level of per capita CO_2 emissions at the beginning of each five-year period; GDP/cap is the average GDP per capita over the five-year period; Energy use/cap is the average energy use per capita over the five-year period; Growth renewable production is the average growth rate of renewable energy supply over the five-year period; Initial Energy use/cap is the level of energy use per capita at the beginning of each five-year period.

4 Results

We first discuss the regression results of equations (2) and (3) to investigate whether CO_2 emissions have converged among the EU countries. We then use these results to investigate the effects of macroeconomic shocks (or variables) and climate and energy policies on emission growth by employing bootstrap method.

Conditional convergence in CO_2 emissions

Before examining in detail the conditional convergence in emissions, we discuss the results of the first stage regressions of the initial per capita CO_2 emissions on the instrument (the initial per capita energy use for country i) and the control variables. The results are reported in table 2. We immediately notice that the F-First stage statistics is significant across all specifications.

Table 2: First-stage regressions. Conditional convergence in CO_2 emissions among EU-15 from 1960 to 2009.

	(1)	(2)
$Log(initialEner.use/cap)$	1.385	1.379
	(0.189)**	(0.188)**
$Log(GDP/cap)$	1.987	-0.160
	(2.849)	(0.100)
$Log(GDP/cap) * PER1$	3.265	5.294
	(2.987)	(1.295)***
$Log(GDP/cap)^2$	-0.104	
	(0.138)	
$Log(GDP/cap)^2 * PER1$	-0.174	-0.273
	(0.146)	(0.066)***
$Log(OilPrice)$	-0.037	-0.038
	(0.022)*	(0.022)*
$Log(Ener.use/cap)$	-0.493	-0.477
	(0.215)***	(0.213)***
R^2	0.986	0.986
F-First Stage	53.95	53.80
Obs	148	148

Notes: First-stage regressions of equation (2) are displayed. Log initial Ener.Use/cap is the log of the energy use per capita at the beginning of period; $Log(GDP/cap)$ is the log of the per capita GDP of country i; $Log(GDP/cap)^2$ is the log of the square of per capita GDP; $Log(OilPrice)$ is the log of the oil price; $Log(Ener.use/cap)$ is the log of the energy use per capita of country i. Tstat are reported in brackets. *,**,*** denote respectively significance at 10%, 5% and 1% level.

Table 3 presents the regression results using the two methods, LSDV and IV-GMM, for the EU-15 countries from 1960 to 2009. The coefficient of convergence is significant and robust across the model specifications implying that the speed of convergence in the EU-15 countries is 0.31.[14] This means that EU-15 countries should be at 5% of the asymptotic value of emission in roughly 10 years, i.e., they should stabilize their per capita emissions, ceteris paribus. A structural break in the relation between emission growth and GDP per capita exists. Before 1990, this relation could be represented by an inverted U-shaped function. The semi-elasticity of emission growth with respect to GDP per capita is -0.05, indicating that an increase of one percent in GDP per capita causes a decrease of 0.05 percentage point in emission growth. Since the mid-1990s, the relation between emission growth and per capita GDP is significantly negative, the semi-elasticity being equal to -0.04. As expected, any increase by one percent in oil price causes a decrease of 0.01 point of percentage in emission growth. The energy use per capita positively impacts emission growth, the semi- elasticity being equal to 0.24. Thus, any climate policy aiming to promote energy efficiency (or a decrease in energy use per capita) can contribute to a decrease in emission growth.

Before turning to the analysis of conditional convergence in CO_2 among all of the EU countries from 1990 to 2009, we check the validity of the instrument by analyzing the results of the first-stage regressions (see table 4). The F-First stage is significant across all specifications. Table 5 presents the regression results of equation (3) for the EU countries over the period 1990-2009. Despite the inclusion of the new Member States in our sample, the null hypothesis of conditional convergence cannot be rejected. The convergence speed is robust to the enlargement of the EU and equal to 0.33 indicating that all EU Member States should be at 5% of the asymptotic value of emissions in roughly 10 years, i.e., around 2020. This result is in line with other studies (Jobert et al., 2010). Our analysis reveals that the relation between emission growth and per capita GDP is statistically different between historical and new Member States. The semi-elasticity of the EU-15 countries (-0.067) is larger than the semi-elasticity of the new Member States (-0.039). The coefficient associated with oil price is statistically significant and equal to -0.012. So, we can argue that fossil fuel price spikes cannot result in a substantial

[14] The speed of convergence is calculated as follows: $-log(1+\beta)$ where β is the coefficient of the level of CO_2 per capita at the beginning of period ($logCO_{2_{i,t-T}}$), see equations (2) and (3).

Table 3: Regressions results. Conditional convergence in CO_2 emissions among EU-15 from 1960 to 2009.

	LSDV	IV-GMM	LSDV	IV-GMM
	(1)	(2)	(3)	(4)
$Log(initialCO_2/cap)$	-0.124	-0.273	-0.125	-0.271
	(0.016)***	(0.032)***	(0.016)***	(0.032)***
$Log(GDP/cap)$	-0.860	-0.715	-0.001	-0.045
	(0.597)	(0.431)*	(0.021)	(0.024)**
$Log(GDP/cap) * PER1$	1.886	2.296	1.075	1.621
	(0.627)***	(0.537)***	(0.277)***	(0.451)***
$Log(GDP/cap)^2$	0.042	0.032		
	(0.029)	(0.021)		
$Log(GDP/cap)^2 * PER1$	-0.096	-0.117	-0.056	-0.084
	(0.031)***	(0.027)***	(0.014)***	(0.023)***
$Log(OilPrice)$	-0.018	-0.011	-0.018	-0.011
	(0.004)***	(0.005)**	(0.004)***	(0.005)**
$Log(Ener.use/cap)$	0.096	0.242	0.093	0.238
	(0.022)***	(0.039)***	(0.022)***	(0.039)***
Fixed Effects	yes	yes	yes	yes
R^2	0.753	0.569	0.748	0.570
Std Error Est.	0.017	0.023	0.017	0.023
Wu-Hausman $\chi^2(1)$		53.32		50.32
Obs	148	148	148	148

Notes: Regression results of equation (2) are displayed. Tstat are reported in brackets. *,**, and *** denote respectively significance at 10%, 5% and 1% level. The initial CO_2/cap for country i (expressed in log) is instrumented with the initial energy use per capita of country i (expressed in log).

decrease in emission growth. However, climate policy especially policy aiming to promote energy efficiency, can have a higher impact on emission growth and the path of convergence (see figure 5). The semi-elasticity of per capita energy use is quite large and reaches 0.33 while an increase of one point of percentage in the growth rate of renewable sources production causes a decrease of 0.07 point of percentage in emission growth.

Table 4: First-stage regressions. Conditional convergence in CO_2 emissions among all EU Member States from 1990 to 2009.

	(1)	(2)
$Log(initialEner.use/cap)$	1.256	1.246
	(0.108)***	(0.104)***
$Log(GDP/cap)$	0.716	-0.220
	(1.991)	(0.087)**
$Log(GDP/cap) * NEU15$	-0.824	0.070
	(2.590)	(0.069)
$Log(GDP/cap)^2$	-0.045	
	(0.096)	
$Log(GDP/cap)^2 * NEU15$	0.043	
	(0.129)	
$Log(OilPrice)$	-0.031	-0.032
	(0.024)	(0.023)
$Log(Ener.use/cap)$	-0.129	-0.101
	(0.190)	(0.177)
$GrowthREproduction$	-0.108	-0.098
	(0.175)	(0.167)
R^2	0.987	0.987
F-First Stage	133.68	141.87
Obs	108	108

Notes: First-stage regressions of equation (3) are displayed. $LoginitialEner.Use/cap$ is the log of the energy use per capita at the beginning of period; $Log(GDP/cap)$ is the log of the per capita GDP of country i; $Log(GDP/cap)^2$ is the log of the square of per capita GDP; $Log(OilPrice)$ is the log of oil price; $Log(Ener.use/cap)$ is the log of the energy use per capita of country i; $GrowthREproduction$ is the average growth rate of the production of renewable sources over each five years period. Tstat are reported in brackets. *,**,*** denote respectively significance at 10%, 5% and 1% level.

Table 5: Regressions results. Conditional convergence in CO_2 emissions among all EU Member States from 1990 to 2009.

	LSDV	IV-GMM	LSDV	IV-GMM
	(1)	(2)	(3)	(4)
$Log(initialCO_2/cap)$	-0.238	-0.286	-0.238	-0.284
	(0.017)***	(0.022)***	(0.017)***	(0.021)***
$Log(GDP/cap)$	-0.499	-0.627	-0.040	-0.067
	(0.477)	(0.374)*	(0.022)*	(0.023)**
$Log(GDP/cap)$*NEU15	0.809	0.808	0.027	0.026
	(0.624)	(0.527)	(0.017)	(0.015)*
$Log(GDP/cap)^2$	0.022	0.027		
	(0.023)	(0.018)		
$Log(GDP/cap)^2$*NEU15	-0.039	-0.039		
	(0.031)	(0.026)		
$Log(OilPrice)$	-0.016	-0.012	-0.015	-0.012
	(0.005)***	(0.005)**	(0.005)***	(0.005)**
$Log(Ener.use/cap)$	0.270	0.351	0.254	0.333
	(0.038)***	(0.043)***	(0.036)***	(0.041)***
$GrowthREproduction$	-0.041	-0.062	-0.055	-0.074
	(0.042)	(0.039)	(0.041)	(0.036)**
Fixed Effects	yes	yes	yes	yes
R^2	0.883	0.870	0.880	0.868
Std Error Est.	0.013	0.013	0.013	0.013
Wu-Hausman $\chi^2(1)$		22.04		20.45
Obs	108	108	108	108

Notes: Regression results of equation (3) are displayed. Tstat are reported in brackets. *,**, and *** denote respectively significance at 10%, 5% and 1% level. The initial CO_2/cap for country i (expressed in log) is instrumented with the initial energy use per capita of country i (expressed in log).

Effectiveness of climate and energy policies

In light of our results, we can discuss the effectiveness of climate and energy policies. From the analysis of the conditional convergence, we know that the EU countries should succeed in stabilizing their carbon emissions in roughly ten years. We employ bootstrap method by using the estimated coefficients of equation (3) to calculate the asymptotic value of per capita carbon emissions if nothing else changes (control variables are at their 2005-2009 value).[15] The results are named *Benchmark Scenario*. To examine the efforts that the EU Member States should make to achieve their targets, we plot figure 6 which presents the asymptotic value of per capita emissions as calculated by the bootstrap (presented by the bars in figure 6) and the targets for carbon emissions as defined by the European Commission (the diamonds in figure 6).[16] The EU Members are classified in descending order of the difference between the carbon emissions target and the asymptotic value of the carbon emissions. We immediately notice that some new Member States (Estonia, Lithuania, Slovakia, Latvia, Bulgaria, Romania, Czech Republic, Poland and Hungary) should converge to their asymptotic value of carbon emissions by 2020 without adopting greener technologies and they could do even better than initially targeted. More surprisingly, Germany, Great-Britain and France belong to this group. Most of the historical Member States should adopt more aggressive climate policies.

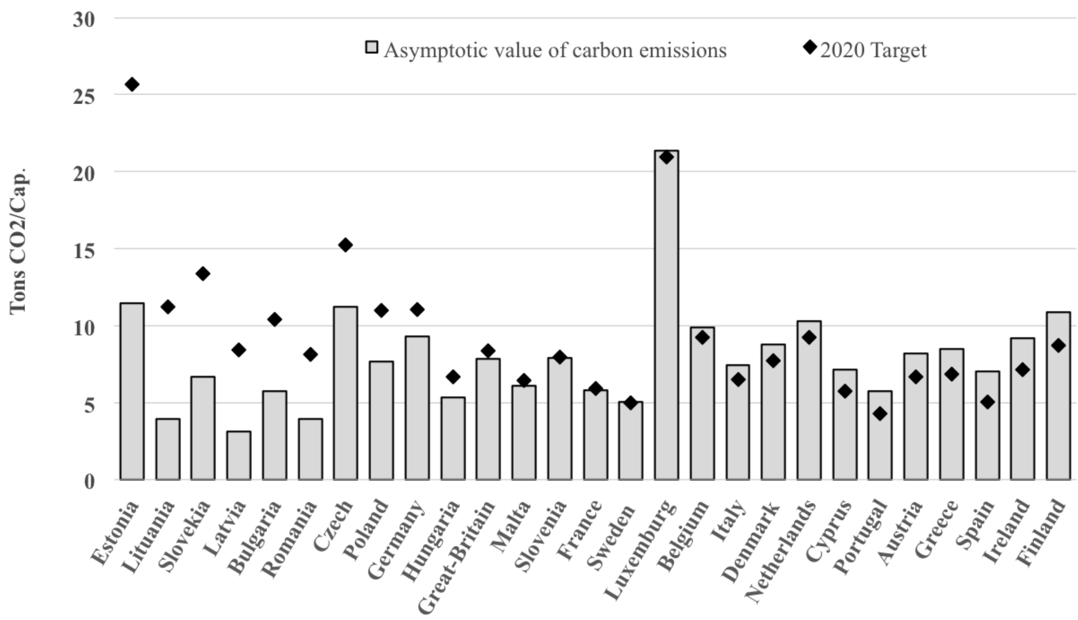
We now analyze how economic factors can affect the efforts that should be made by each country and how climate and energy policies can help them to meet their country targets (see figure 5). We define four scenarios: 1)under the *Scenario GDP*, we employ GDP per capita forecasts for the period 2020-2024 made by the EIA;[17] 2) the average oil price rises from US $75 per barrel in 2005-2009 to US$105 in 2020-2024 as projected by EIA (EIA, 2014) –*Scenario Oil Price*–; 3) the EU countries decrease their energy use per capita by 20% below their 1990 levels–*Scenario Energy Use*–; 4) the growth rate of renewable production increases by 20% in all Member States– *Scenario Renewable Sources*.

[15] We run 5,000 iterations. The results are robust if we increase the number of iterations to 10,000.

[16] The European Commission has defined the CO_2 emission reduction targets as the percentage reduction of CO_2 emissions below their 1990 levels (see figure 1).

[17] The annual average growth rate should be equal to 1.06% for EU-OECD Members and to 2.48% for EU-NonOECD Members EIA (2014).

Figure 6: Country's emissions target and country's asymptotic value of carbon emissions under the *Benchmark Scenario*



Notes: The bar represents the country's asymptotic value of carbon emissions under the *Benchmark Scenario*. Each diamond represents the country's specific target.

In table 6, we present the difference between each country's specific target and the asymptotic value of carbon emissions as calculated by the bootstrap under the *Benchmark Scenario* and under each alternative scenario. A positive difference means that the asymptotic value of carbon emissions is below the target, meaning the country can meet its 2020 target. A negative difference means that the asymptotic value of carbon emissions is above the target, meaning the country should adopt a more aggressive policy to reach its target. The higher the difference, the greater the effort the country needs to make. To investigate which economic factor or which climate policy may help the EU Member States to meet their target, we compare the results of the *Benchmark Scenario* with the results of the four alternative scenarios. We can immediately notice that economic growth does not impact the efforts that should be made by the EU members. The rise in oil price (or more generally in fossil fuel price) does not cause a substantial decrease in growth emissions, and thus, also does not impact the asymptotic value of carbon emissions with the exception of Luxemburg, France and Slovenia. Improvement in energy efficiency and investment in renewable sources can help EU Members to reach their targets. If Sweden and Luxemburg increase their share of renewable sources in total energy production, they are on track to meet their targets, ceteris paribus. However, the most effective means to reduce carbon emissions is energy efficiency.

Table 6: Difference between each country's specific target and asymptotic value of carbon emissions under the *Benchmark Scenario* and alternative scenarios (tons of CO_2 per capita)

EU Member States	*Scenarios*				
	Benchmark	*GDP*	*Oil Price*	*Energy Use*	*Renewable Sources*
Estonia	14.18	14.50	14.34	16.82	14.63
Lithuania	7.27	7.53	7.33	8.17	7.42
Slovakia	6.69	6.88	6.78	8.23	6.91
Latvia	5.29	5.50	5.34	6.01	5.44
Bulgaria	4.70	5.08	4.78	6.02	4.99
Romania	4.23	4.23	4.29	5.13	4.42
Czech republic	4.03	4.35	4.19	6.61	4.44
Poland	3.28	3.50	3.39	5.05	3.56
Germany	1.72	2.14	1.85	3.86	2.01
Hungary	1.32	1.48	1.40	2.55	1.48
Great Britain	0.55	0.90	0.66	2.34	0.80
Malta	0.35	0.75	0.43	1.75	0.54
Slovenia	0.08	0.30	0.19	1.89	0.38
France	0.07	0.34	0.15	1.41	0.31
Sweden	-0.09	-0.14	-0.02	1.07	0.14
Luxemburg	-0.39	0.58	-0.09	4.52	0.57
Belgium	-0.64	-0.19	-0.50	1.63	-0.46
Italy	-0.94	-0.60	-0.83	0.78	-0.66
Denmark	-1.01	-0.61	-0.89	1.00	-0.62
Netherlands	-1.07	-0.60	-0.92	1.29	- 0.76
Cyprus	-1.37	-0.91	-1.27	0.27	-1.18
Portugal	-1.47	-1.20	-1.39	-0.14	-1.27
Austria	-1.54	-1.10	-1.42	0.35	-1.19
Greece	-1.58	-1.19	-1.46	0.36	-1.20
Spain	-1.93	-1.19	-1.84	-0.32	-1.71
Ireland	-2.04	-1.61	-1.91	0.07	- 1.83
Finland	-2.16	-1.67	- 2.01	0.34	-1.60

Notes: We calculate the difference between each country's specific target and the asymptotic value of carbon emissions as calculated by the bootstrap. A positive sign means that the country emits less than its carbon target, meaning that the country can meet its target. A negative sign means that the country's emissions are higher than its carbon target, indicating that the country should adopt a more aggressive policy. Under the *Benchmark Scenario*, we assume that carbon emissions are stabilized and that the control variables are at their 2005-2009 level. Under the *Scenario GDP*, we employ GDP per capita forecasts from EIA (2014). The annual average growth rate should be equal to 1.06% for EU-OECD Members and to 2.48% for EU-Non OECD Members. Under the *Scenario Oil Price*, the average oil price rises from US $75 per barrel in 2005-2009 to US$105 in 2020-2024 as projected by EIA (EIA, 2014). Under the *Scenario Energy Use*, the EU countries decrease their energy use per capita by 20% below their 1990 levels. Finally, under the *Scenario Renewable Sources*, the growth rate of renewable production increases by 20% in all Member States.

5 Conclusion

We investigate per capita CO_2 emission trends across Member States to examine the effectiveness of climate and energy policies. We test the assumption of a β convergence in per capita CO_2 emissions, conditional upon per capita output, world oil price, energy use per capita and investment in renewable sources. As predicted by the literature on β-convergence, we find a decreasing relation between emission growth and the initial level of CO_2 per capita. The EU-15 countries should stabilize their per capita carbon emissions in roughly 10 years, i.e., 2020. This result holds if we include the new Member States. We also examine how the country's characteristics may affect the convergence process. A decreasing relation between emission growth and GDP per capita among historical Member States after the 1990s exists. This result holds if new Member States are included. A shock on fossil fuel price should have a limited impact on emission growth, ceteris paribus while investment in renewable energy and in energy efficiency should affect negatively emission growth (see figure 5). By using bootstrap method, we show that the burden of emissions reduction is not shared equally among the EU countries. Historical Member States like Germany, Great-Britain and France can hit their carbon target by 2020 without increasing their investments in green technologies or improving their energy efficiency. Other historical Member States should invest in more energy efficient technologies to reach their domestic targets. The new Member States are expected to be well below their domestic targets in 2020 even if there is an increase in per capita income or in oil price.

Our findings have important implications for EU climate policy. Since most of the EU countries must make substantial efforts to reach the 2020 target, the 2030 target of 40% reduction seems to be out of reach without quite substantial investment in renewable technology and energy efficiency. But, investment in green technologies seems to have slowed down. The sovereign debt crisis in Europe has crimped funding for green projects and investment in energy efficiency. The rise of technologies tapping cheap unconventional resources like shale gas and shale oil has caused the recent decline of crude oil price and has dented prospects for renewable technologies. After the Fukushima nuclear disaster, some countries like Germany have stepped up its phase-out of nuclear technology, although the latter emits almost zero carbon emissions, while increasing their reliance on highly polluting coal sources.

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