Energy Efficiency in Transition Economies: Is There Convergence Towards the EU Average?

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Energy Efficiency in Transition Economies: Is There Convergence Towards the EU Average?

Summary

This paper investigates the relationship between energy intensity in the 12 countries of Eastern Europe that can be considered as in transition to a full market economy, and that of the present EU members. The raw data shows some evidence of convergence, and a carefully estimated econometric model of lagged adjustment confirms this. On average, a 1% decrease in the *per capita* income gap between developed and transition economies leads to a decrease in the energy intensity growth rate of a transition country by 0.7%. There are differences in the rate of convergence across countries, and these depend on two parameters that are allowed to vary across countries: η, the elasticity of desired energy intensity with respect to the per capita income gap; and μ, the rate at which actual energy intensity adjusts to the desired energy intensity. The countries with the fastest convergence rates given these parameters are the Czech Republic, Bulgaria, Croatia and Turkey.

The forecast values for energy intensity and actual energy demand levels of seven transition countries were estimated. Results show that the energy intensities of transition countries except Estonia converge to EU levels significantly. On the other hand, actual energy demand levels between 2000 and 2020 show an increasing demand in all 7 countries despite the reductions in energy intensity. Therefore, it will not be feasible to use as a target a non-increasing level of total energy consumption.

Keywords: Energy, Convergence, Transition

JEL Classification: C33, Q49

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1. Introduction

As the transition countries of East and Central Europe (CEE) move towards a market based system, the expectation is that key indicators of economic, social and environmental performance will converge to that of the existing market economies. Given the proximity of the CEE to the EU, and given the moves to EU membership, this convergence should be specially close between the transition countries and the EU.

A considerable amount of research has been done on convergence of *per capita* income between the poorer and richer countries of the world. Economies are assumed to be converging toward one another if the income of poorer economies grows faster over time relative to that of the richer economies, thus reducing inter-country income inequality. Sala-i Martin (1996) studied and compared the speeds of income convergence across various datasets, which included a sub-sample of OECD countries, states within the United States, prefectures of Japan, and regions within several European countries. Across the datasets, the speed of convergence was found to be similar at about 2% per annum. Kaitila (2004) studied income convergence among two groups of countries: 15 EU countries, and 7 CEEC countries, and found the rate of convergence for each of the two groups to be approximately 0.02% and 0.03%, respectively. Other literatures, for instance those written by Bunyaratavej and Hahn (2002), Wagner and Hlouskova (2002), and Dela Fuente (2003), extended their analysis of income growth to include other elements besides income, e.g., employment, labor productivity, technological diffusion and exchange rate volatility. For 15 EU member countries, Bunyaratavej and Hahn (2002) found an income convergence rate of 1.6%; while Wagner and Hlouskova (2002) looked at 14 EU countries (without Luxembourg) and found the speed of convergence to be between

0.01% to 0.02%. On the other hand, Dela Fuente (2003) found 0.03% for the OECD countries.

This paper seeks to extend the analysis of convergence to the area of energy intensity between the transition countries and the EU. As real incomes converge, one might expect energy intensity also to converge. The case for such convergence, however, has not been made. The relationship between GDP and Total Primary Energy Supply (TPES) is found to be broadly log-linear, with an elasticity of TPES with respect to GDP of 0.75 in developed countries and one for developing countries (the average across all countries is 0.85). These results are from WEC (2000), and are based on data from 1982. The significant differences between developing and developed market economies have two origins: (a) the transformation of some unaccounted non-commercial energy into commercial energy when the economy grows; and (b) the relocation of some industries because the economic inputs, mostly labour and energy, are cheaper in the developing countries than in the developed countries. Most importantly, however, with these elasticities, even if there is convergence in real *per capita* income, there will not be convergence in energy intensities[4].

Why is the evolution of energy intensity important? First, it is useful for energy policy makers to know how energy demand will grow, in the face of major changes in economic structure and system of economic management. Traditional energy demand forecasting models, while useful, find it difficult to incorporate such structural changes. Second, there is an active policy debate within the transition countries themselves as to whether total energy use should grow as GDP grows. Presently these countries have a lower level of energy efficiency (higher intensity) than the current EU member states. If convergence is fast enough, and if growth is modest, there may be no increase in total energy use. In that case a target of non-increasing energy may be feasible and desirable as part of a sustainability strategy. If, on the other hand, convergence is slow and growth rapid, it will not be feasible to set a target of this kind. Finally the analysis will show which countries are converging more rapidly and which are not. With further investigation of the reasons for these differences, we will be able to develop policies to promote convergence.

This study seeks, therefore, to analyze income growth and energy efficiency for the transition countries in light of their integration to the European Union (EU). Energy efficiency, in this study, is measured by energy intensity – the amount of energy required to produce a given unit of output. A transition country's rate of energy intensity is assumed to be a function of the disparity in income between the transition country and an *average EU* country. Our analysis will be divided into two parts. First, we aim to observe the trend in the income disparity variable before we examine its impact on energy intensity.[5] The movement of this exogenous variable over time is critical to determining the direction of the energy intensity growth rate later on. Subsequently, we will test the relationship between the said two variables, together with other regressors. Particularly, we aim to: (a) determine how energy efficiency, in general, is evolving in the transition economies; (b) test the assumption that energy efficiency in these economies, which are increasingly being linked to the EU, is converging to that of the EU; and (c) ascertain the likely path for energy consumption until the year 2020, both in absolute terms and relative to the EU.

The paper is organized as follows. Section 2 provides the source and description of data used in the study. Section 3 shows how the convergences in real per capita income and energy intensity are estimated; while Section 4 gives a description of the estimation method applied and the regression results. The energy consumption in the focus countries is forecasted until 2020 in Section 5. Section 6 closes the paper with summary and conclusions.

2. Source and Description of Raw Data

This paper uses data collected from the country ministries and from the International Energy Agency (IEA, 1999a, 1999b, 2000a, 2000b). The IEA constructs the statistics from official data, and when necessary, estimates have been made based on information obtained from industry sources and other international organizations. Since countries themselves may have different criteria and definitions for their data, the IEA makes the necessary adjustments so that the data would adhere to international definitions. Annex 1 provides the raw data used in this study.

2.1. Energy consumption (1990-2000)

The Total Primary Energy Supply (TPES) data were used. TPES is made up of production + imports – exports – international marine bunkers ± stock changes.[6] A country's *energy intensity*, which is defined as the amount of energy required to generate a unit of economic output, is derived by dividing TPES by GDP. The unit of measure used in the study is *tons of oil equivalent (toe) per 1995 US dollar (PPP)*.

2.2. Gross domestic product (1990-2000)

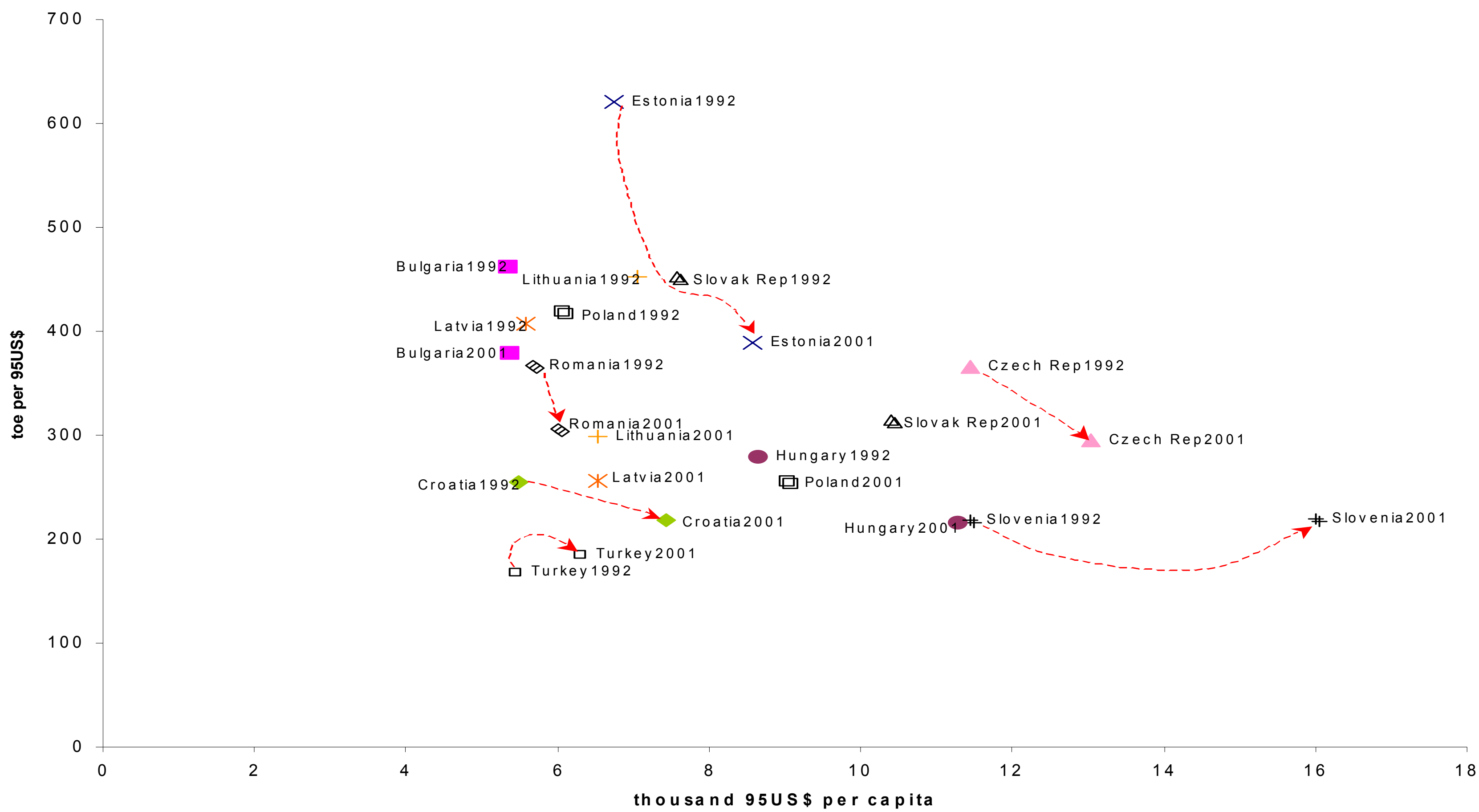
The gross domestic product (GDP) data for individual countries have been adjusted by IEA to 1995 price levels and converted to US dollars using the purchasing power parities (PPP). PPP are the rates of currency conversion that eliminates the price level differences between countries. In order to make the GDP variable comparative across countries, a country's GDP was divided by its population. The unit of measure used for GDP is *thousand 1995 US dollars (PPP) per capita*.

The energy consumption and GDP data were collected for the fifteen European Union member countries (Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, Sweden and United Kingdom) and twelve transition countries (Bulgaria, Croatia, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, Slovak Republic, Slovenia and Turkey). The average energy intensity and per capita income of the EU countries were calculated, where the resulting values are used for a *representative EU country* (i.e., "average EU"). In the following sections, the energy intensity and per capita income of transition countries will be compared with those of the *average EU*.

Figure 1 shows a comparison of the energy intensity and real *per capita* income of the twelve developing countries between 1992 and 2001. All countries in 2001, excluding Lithuania and Turkey, showed an increase in real per capita GDP that is accompanied by a decrease in energy intensity from the 1992 levels.

On the other hand, the growth rates of energy intensity and real per capita GDP of the transition countries between 1992 and 2001 are compared with those of an *average EU* (Table 1). In terms of per capita income, six of the twelve transition countries have larger per capita income growth rates than that of the *average EU* over the given period. The largest being is Poland's per capita income growth rate. By looking at the raw data, there appears to be convergence in energy efficiency, i.e., a faster decline over time in energy use by a transition country relative to that of the *average EU*. The change in energy intensity from 1992 to 2001 for an average European Union member country is negative 12%. Most of the transition countries have a much greater decline over the same period than an *average EU*, but Poland depicted the biggest decline in energy intensity.

Figure 1: Energy intensity and Real per capita GDP, 12 Transition Countries, 1992 and 2001



We can also compare each country's growth rates in energy intensity and per capita income between 1992 and 2001 relative to those of the *average EU* (see Figure 2). Here, the gap between the energy intensity growth rates and per capita income growth rates of a "transition country *i*" and "average EU" are calculated and plotted in the graph. The energy intensity gap tells us the following relationship over the said period:

a.1. A larger gap means %ΔEU > %ΔTransition Country, which implies that the transition country is becoming relatively less energy intensive than the *average EU*.

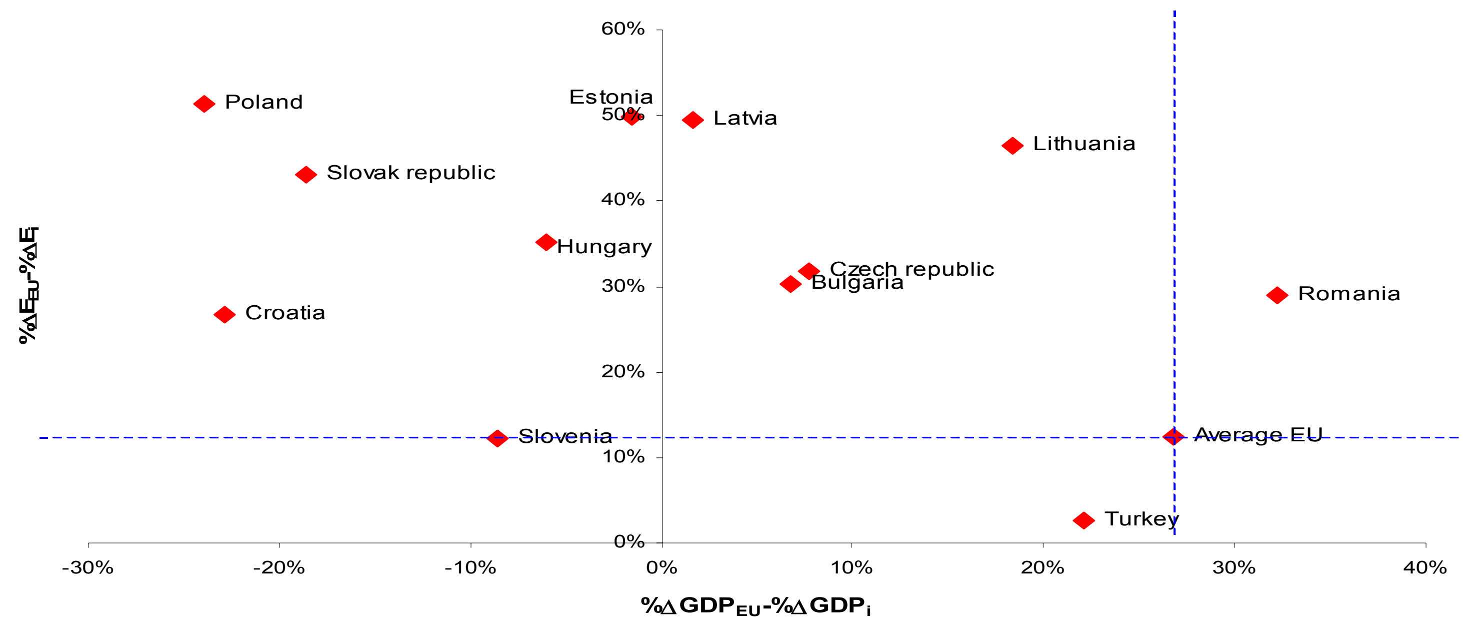
a.2. A smaller gap means %ΔEU > %ΔTransition Country, which implies that the transition country is becoming relatively more energy intensive than the *average EU*.

On the other hand, the per capita income gap, gives us the following:

a.3. A larger gap implies that the transition country has a smaller increase in income between 1992 and 2000 than the *average EU*.

a.4. A smaller gap implies that the transition country has a larger increase in income between 1992 and 2000 than the *average EU*.

Figure 2: Comparison of Transition Countries with respect to their Energy Intensity Growth Rates and Real Per Capita GDP Growth Rates (between 1992 & 2001) Relative to those of the Average EU



Desirable relationships (e.g., Poland versus the 11 other countries):

- Energy Intensity Gap: Calculated as [100 x [(E_{EU2001}-EEU_{1992})/E_{EU1992}] – [(E_{i2001}-Ei_{1992})/E_{i1992})]]. The larger the gap means that the transition country is becoming relatively less energy intensive than the *average EU* over the given period (i.e., obtained as the point moves upward the Y-axis).
- Per Capita Income Gap: Calculated as [100 x [(GDP_{EU2001}-GDP_{EU1992})/EEU_{1992}] – [(GDP_{i2001}-GDP_{i1992})/E_{i1992})]]. The smaller the gap implies that the transition country has a bigger change in income between 1992 and 2001 than the *average EU* (i.e., obtained as the point moves towards the left of the X-axis).

The desirable outcome is a combination of the relationships (a.1) and (a.4). Using Figure 2, we can weigh the performance of one country against another. For example, *Latvia* meets the two conditions better as compared to Bulgaria, Czech Republic, Romania, Lithuania and Turkey; while *Poland* performs the best among all the twelve transition countries in satisfying the said two conditions. The figure also points to two other important features of the data:

- Energy intensity declined in all EU countries except Slovenia and Turkey
- Between 1992 and 2000, *per capita* income growth was greater for six countries: Croatia, Estonia, Hungary, Poland, Slovak Republic and Slovenia, than for the EU on average.

3. Estimation Model

First, we will analyse the convergence toward the average per capita GDP level of the countries in the study (15 EU countries and 12 transition countries). Next, we will estimate the relationship between energy intensity and per capita income disparity between the EU and developing countries. The following models are applied.

3.1 Dependent variable: Real per capita GDP growth rate

The Baumol specification of β-convergence has been employed by various studies to test the convergence in income among a group of countries:

$$\ln(y_{i,t} / y_{i,t-1}) = \alpha + \beta \ln(y_{i,t-1}) + \varepsilon_{i,t} \quad (1)$$

where $\ln(y_{i,t-1})$ refers to per capita income of country *i* at time *t*, $\ln(y_{i,t} / y_{i,t-1})$ is the per capita income growth rate for a time period, and ε is the error term. When $\hat{\beta}$ is negative, there is β-convergence. It implies that the growth rate of per capita income is negatively related to the initial level of income, which further means that the relatively poor economies grow faster than the rich economies (Sala-i Martin, 1996).

3.2 Dependent variable: Energy intensity growth rate

We take a top-down approach and see whether there has been convergence in energy intensity and what factors determine that rate of convergence. The model is as follows:

Let E_{it} - total primary energy consumption in country *i* at time *t*;

e_{it} - primary energy consumption per capita in country *i* at time *t*;

P_{it} - population of country *i* at time *t*;

Y_{it} - total national income (GDP) of country *i* at time *t*;

y_{it} - per capita income or GDP of country i at time t;

ε_{it} - primary energy intensity of national income (GDP) in country i at time t;

y_{ut} - average per capita income or GDP of the EU i at time t;

ε_{ut} - primary energy intensity of national income (GDP) for the EU at time t;

Define:

$$e_{it} = \frac{\varepsilon_{it} \times Y_{it}}{P_{it}} \quad (2)$$

$$e_{it} = \varepsilon_{it} \times y_{it} \quad (3)$$

As y_{it} increases, e_{it} will also increase. As ε_{it} decreases, e_{it} will also decrease.

We are interested to understand the evolution of e_{it} over time in transition economies. Particularly, we would like to answer the following questions: (a) What is expected to happen to e_{it} for transition countries over next 10 years?; (b) What is the expected evolution of e_{it} for transition country relative to EU countries?

We can define the evolution of ε_{it} in terms of convergence with EU countries:

$$\varepsilon_{it}^{*} = A(\frac{y_{ut}}{y_{it}})^{\eta}\varepsilon_{ut} \quad (4)$$

where ε_{it}^{*} is the desired energy intensity in country 1; A is a constant to be determined; and η is the elasticity of adjustment. A value of 0.5, for example, would imply that a one percent reduction in the income gap would result in a 0.5 percent reduction in the energy intensity gap.

In addition, we expect the adjustment to be lagged because of many factors. So we postulate the following:

$$\varepsilon_{it} = \varepsilon_{i,t-1}(\frac{\varepsilon_{it}^{*}}{\varepsilon_{i,t-1}})^{\mu} \quad (5)$$

hence,

$$\ln\varepsilon_{it} = \ln\varepsilon_{i,t-1} + \mu\ln\varepsilon_{it}^{*} - \mu\ln\varepsilon_{i,t-1} \quad (6)$$

But

$$\ln\varepsilon_{it}^{*} = \ln A + \eta\ln(\Delta y_{t}) + \ln\varepsilon_{ut}\text{, where } y_{ut} - y_{it} = \Delta y_{t} \quad (7)$$

so

$$\ln\varepsilon_{it} = (1-\mu)\ln\varepsilon_{i,t-1} + \mu[\ln A + \eta\ln(\Delta y_{t}) + \ln\varepsilon_{ut}] \quad (8)$$

$$\ln\varepsilon_{it} = \mu\ln A + (1-\mu)\ln\varepsilon_{i,t-1} + \mu\eta\ln(\Delta y_{t}) + \mu\ln\varepsilon_{ut} \quad (9)$$

Unfortunately, equation (9), is over determined for the parameters μ, η, A. This can be seen by redefining the terms in (9) as:

$$\ln \varepsilon_{it} = F + B \ln \varepsilon_{i,t-1} + C \ln \Delta y_t + D \ln \varepsilon_{ut} \tag{10}$$

so that,

- $\eta = \dfrac{\hat{C}}{\mu}$
- $A = \exp\left(\dfrac{\hat{F}}{\mu}\right)$
- $\mu = \hat{D}$ but $\hat{B} = 1 - \mu$ thus $\mu = 1 - \hat{B}$.

Based on the above results, which value of μ should be used? We do not know which one to use nor which one is correct because both are only estimates. Fortunately, this problem can be addressed by further transforming Equation (9) as:

$$\begin{aligned} \ln \varepsilon_{it} &= \mu \ln A + \ln \varepsilon_{i,t-1} - \mu \ln \varepsilon_{i,t-1} + \mu\eta \ln(\Delta y_t) + \mu \ln \varepsilon_{ut} \\ (\ln \varepsilon_{it} - \ln \varepsilon_{i,t-1}) &= \mu \ln A + \mu(\ln \varepsilon_{ut} - \ln \varepsilon_{i,t-1}) + \mu\eta \ln(\Delta y_t) \\ (\ln \varepsilon_{it} - \ln \varepsilon_{i,t-1}) &= B + C(\ln \varepsilon_{ut} - \ln \varepsilon_{i,t-1}) + D \ln(\Delta y_t) \end{aligned} \tag{10.2}$$

and then running the regression on:

$$\ln\left(\frac{\varepsilon_{it}}{\varepsilon_{i,t-1}}\right) = B + C \ln\left(\frac{\varepsilon_{ut}}{\varepsilon_{i,t-1}}\right) + D \ln \Delta y_t + error\ term \tag{10.3}$$

where ε_{it} is the energy intensity of Transition Country *i* at period *t*; $\varepsilon_{i,t-1}$, energy intensity of Transition Country *i* lagged one period; ε_{ut}, average energy intensity of European Union at period ; and Δy_t refers to the gap between average per capita GDP of EU at period *t* and per capita GDP of transition Country *i* at period *t* (i.e., $\Delta y_t = \bar{y}_{ut} - y_{it}$). Furthermore equation (10-3) will give,

- $\mu = \hat{C}$
- $\eta = \dfrac{\hat{D}}{\mu} = \dfrac{\hat{D}}{\hat{C}}$
- $A = \exp\left(\dfrac{\hat{B}}{\mu}\right) = \exp\left(\dfrac{\hat{B}}{\hat{C}}\right)$.

As a result, all the parameters of interest are now exactly determined.

The energy intensity of a transition country is greater than the energy intensity of an EU country (i.e., richer countries are more energy efficient) as was presented in Table 1. As the income of a transition country increases (faster than the EU), it is assumed that the transition country will become more energy efficient.

The model (10.3) will therefore test the following hypothesis:

- If $\hat{D} > 0$ - depicts a direct relationship between the dependent variable and Δy_t. Hence a decrease (increase) in the gap of per capita GDP between EU and Transition Country *i*, decreases (increases) Transition Country *i*'s primary energy intensity growth rate by $\hat{D}\%$ (i.e., Convergence is implied).
- If $\hat{D} < 0$ - depicts a negative relationship between the dependent variable and Δy_t. This means that a decrease (increase) in the gap of per capita GDP between EU and Transition Country *i*, leads to an increase (decrease) in Transition Country *i*'s primary energy intensity growth rate by $\hat{D}\%$ (i.e., Divergence is implied).

4. Estimation Method and Regression Results

To find out what estimation method should be employed given the available information, the null hypothesis of equal intercepts is tested. If the null is accepted, the data are pooled and Ordinary Least Squares (OLS) is used. If the null hypothesis is rejected, a Hausman test is then applied to test if there is no correlation between the composite error and the regressor. If the null is accepted, the random effects estimator is used; if the null is rejected, the fixed effects estimator is used.

The appropriateness of a pooled or panel regression is determined by performing an F-test on the country dummy variables. The F-test rejects the null hypothesis of homogeneity across each country at 5% level of significance, which indicates that OLS is not applicable but panel data estimation via fixed effects or random effects. Then, the Hausman test was employed to test the null hypothesis that there is no correlation between the composite error and explanatory variables. Under the null hypothesis, the random effects model is applicable; however, the Hausman test rejected the null hypothesis at 5% significance level. This implies that the fixed effects model is appropriate.

For both equations (10.2) and (10.3), the two-way fixed effects model is used to capture the heterogeneity across countries and across time. Since we are considering transition countries here, we would need to consider time effects that capture the significant events at a certain time that have an impact on their respective energy intensity and income growth. Also, slope dummies are also added to Equation 10.3 to make possible the calculation of key parameter estimates (μ, η, A) for each country being studied.

$$\ln(y_{i,t}/y_{i,t-1}) = \alpha + \beta \ln(y_{i,t-1}) + \delta_j CS_j + \gamma_k TS_k + errorterm \quad (1.2)$$

$$\ln\left(\frac{\varepsilon_{it}}{\varepsilon_{i,t-1}}\right) = B + C\ln\left(\frac{\varepsilon_{ut}}{\varepsilon_{i,t-1}}\right) + D\ln\Delta y_t + \theta_j CS_j + \rho_k CS_k X_1 + \rho_k CS_k X_2 + \phi_m TS_m + \varepsilon_{it} \quad (10.4)$$
$$Y = B + CX_1 + DX_2 + \theta_j CS_j + \rho_k CS_k X_1 + \rho_k CS_k X_2 + \phi_m TS_m + \varepsilon_{it}$$

where ε is the error term; CS, the dummy variable for each country *i* where Turkey is the base; 1 – Bulgaria; 2 – Croatia; 3 – Czech Republic; 4 – Estonia; 5 – Hungary; 6 – Latvia; 7 – Lithuania; 8 – Poland; 9 – Romania; 10 – Slovak Republic; 11 – Slovenia; and TS, the dummy variable for each time period (1991-2000); where 2001 is the base year.

Table 2 shows the key results from using equation (1.2). $\hat{\beta}$ is negative, hence the assumption of per capita income convergence is supported. Overall, the convergence rate within the EU and transition countries is estimated to be about 0.30% per year during 1990 through 2001, and is statistically significant at 5% level.

Note that this figure complements that obtained by Kaitila (2004), who found the convergence rate to be about 0.03% **between the transition countries themselves**. However, we should note that his study used information only from seven transition countries, covered a shorter time period (1995 to 2001), and analyzed the income convergence within this group of seven countries.

With regard to the convergence of energy intensity in the transition countries, the regression results from using equation (10.4) are provided in Table 3. The coefficient estimates of the key explanatory variables are significant at 5% level. Recall that the convergence hypothesis is supported when the coefficient of Δy_t (denoted by X_2 in Equation 10.4) is positive, implying that income disparity and energy intensity growth rate depicts one of the two direct relationships: (a) "Relationship 1" - when income gap increases, energy intensity growth rate increases; or (b) "Relationship 2" - when income gap decreases, energy intensity growth rate decreases. It has been earlier established that there is a β-convergence of the real per capita income in the focus countries, which indicates that the transition countries (relatively poorer economies) are growing faster than the EU countries (wealthier economies), and further implies that the income inequality is decreasing. This suggests that "Relationship 2" is the appropriate one to use in interpreting the results in Table 3. Taking into account that each country has an estimate for $\hat{D}$ based on equation (10.4), the average of $\hat{D}$ was calculated. **Therefore, on average, a 1% decrease in the *per capita* income gap between the EU and transition economies leads to a decrease in the energy intensity gap of 0.7%.**

Not all estimated coefficients of the slope dummy variables are statistically significant individually, however, an F-test on the said coefficient estimates shows that they are jointly significant at 5% level. By using the two-way fixed effects, we are assuming that the intercept varies across the 12 transition countries and across the 11 time periods. Specifically, the coefficient estimates of the dummy variables intend to measure the shifts in the regression line that arise from unknown variables (or variables whose influence may have been omitted in the estimation), therefore alleviating a specification error.

Recall that we are interested to estimate the following parameters, μ, η, A. From Table 3, one can also calculate the parameter estimates for each country and the average of these estimates for the entire sample. The variances of $\hat{\mu}$, $\hat{\eta}$ and $\hat{A}$ were derived using the following formula: $V(g(x)) = (\partial g / \partial x)' V(x)(\partial g / \partial x)$, where $(\partial g / \partial x)$ is a vector whose *i*th element is the partial *g* with respect to the element of *x* (Kennedy, 1998). The critical value of a t-statistic at 20% significance level for 89 degrees of freedom is about 1.30. Based on this, only the average values of $\hat{\mu}$ and $\hat{\eta}$ are found to be statistically significant. A larger margin of error is considered due to the short period used in the study (12 years) as compared to other literatures studying convergence, which uses more than 20 years worth of data.

Table 4 shows the countries with a statistically significant $\hat{\eta}_i$ at 20% level. These countries are Bulgaria, Croatia, Czech Republic, Hungary, Romania and Turkey. $\hat{\eta}_i$ refers to degree of adjustment between the average of the EU and a transition country. A value of one indicates that, in 'equilibrium' the energy intensity gap closes as fast as the income gap does; a value less than one implies the energy intensity gap closes more slowly and a value greater than one implies it closes more rapidly. Hence the values in Table 4 suggest the most rapid closure of the energy intensity gap for Turkey, followed by Croatia, and Bulgaria. Hungary, Romania and Czech Republic, on the other hand have a slower rate of convergence.

The estimated $\hat{\mu}_i$ was also obtained for each country together with the standard error and t-statistics (Table 5), where all countries except Slovenia have statistically significant $\hat{\mu}_i$ at 20% level. Notice also that countries like Bulgaria, Croatia and Turkey have a slower convergence in equilibrium for per capita GDP than for energy intensity.

The values in Table 5 imply that an increase in the **desired** energy intensity of 1% at year *t*, would lead to an increase in actual energy intensity in that year by: 0.63% in Bulgaria; 0.77% in Croatia; 0.80% in Czech Republic; 1.05% in Estonia; 1.21% in Hungary; 0.12% in Latvia; 1.03% in Lithuania; 0.94% in Poland; 0.91% in Romania; 0.57% in Slovak Republic; and 0.71% in Turkey. Another interpretation of $\hat{\mu}_i$ is that 50% of the full adjustment to a new equilibrium value occurs in (ln 0.5/ln(1-$\hat{\mu}_i$)) (Greene, 1990). Thus, in the case of Bulgaria 50% of the adjustment occurs in 0.7 of one year, and so on for the other countries. If the countries were ranked according to their speeds of adjustment, $\hat{\eta}_i$ and $\hat{\mu}_i$, the result is as follows starting from the country with the slowest adjustment speed (Table 6)[7].

5. Forecasts for Energy Efficiency and Energy Demand in Transition Countries

Two types of energy intensity levels are calculated in this section: desired (ε_{it}^*) and actual (ε_{it}). The desired energy intensity levels (ε_{it}^*) of the transition countries are derived using equation (4), thus they are a function of the ratio of the *average EU*'s income to the transition country *i*'s per capita income, and the average energy intensity level of EU at period *t*. On the other hand, the actual energy intensity level at period *t* is assumed to be a function of the previous year's level and ε_{it}^*, and is thus derived by employing equation (5). Based on this actual energy demand is also forecasted, using equation (2).

In order to calculate the energy intensity forecasts thru the year 2020, assumptions were made concerning the income and population growth rate of the countries, as well as the growth rate of EU's energy consumption as seen below (Table 7). Also, the average parameter estimates of the countries (excluding Slovenia[8]) were taken, $\overline{\hat{\eta}}$ and $\overline{\hat{\mu}}$, which are both statistically significant. Doing so would still account for the heterogeneity of the countries, instead of performing an econometric regression without the dummy variables (e.g., equation 10.3) to obtain the average parameter estimates for the whole sample. On the other hand, the value of $\overline{\hat{A}}$ derived in the same way as $\overline{\hat{\eta}}$ and $\overline{\hat{\mu}}$ is poorly determined, so it was not used. Instead, we took the value which minimizes the sum of squared deviation of the countries' actual and desired energy intensity levels. This number varies among the countries and ranges between 0.75 to 1.06. Figures 3 to 9 illustrate the actual energy intensity levels of a particular transition country (ε_{it}) against that of EU. Annex 2 shows the calculated total energy demand for each transition country per annum and compares them with the energy demand levels of the *average EU*. The overall trend for each country within the 20-year period (2000-2020) is increasing, but the average increase in demand per year is slight.

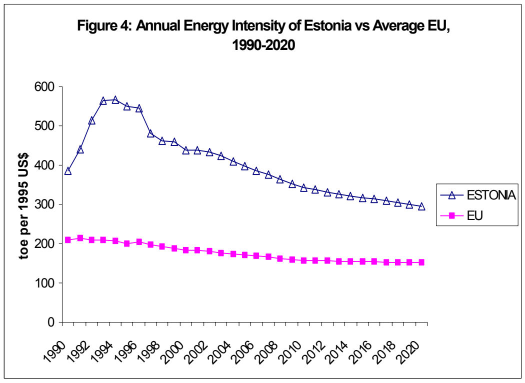


Figure 4: Annual Energy Intensity of Estonia vs Average EU, 1990-2020

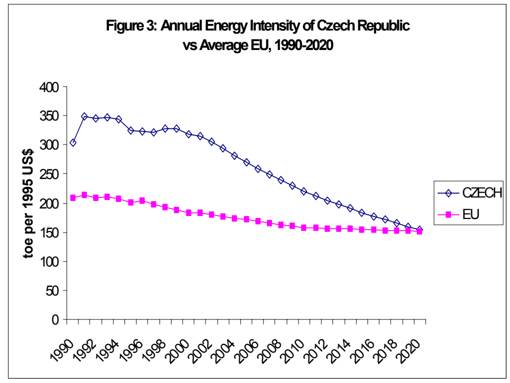


Figure 3: Annual Energy Intensity of Czech Republic vs Average EU, 1990-2020

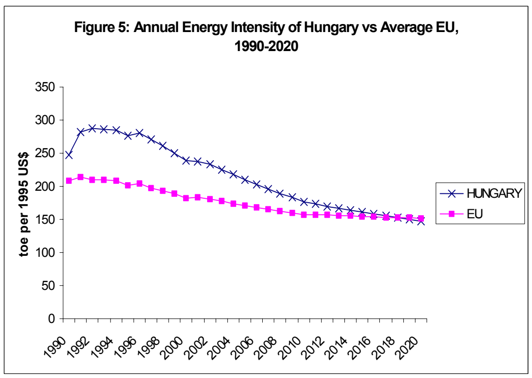


Figure 5: Annual Energy Intensity of Hungary vs Average EU, 1990-2020

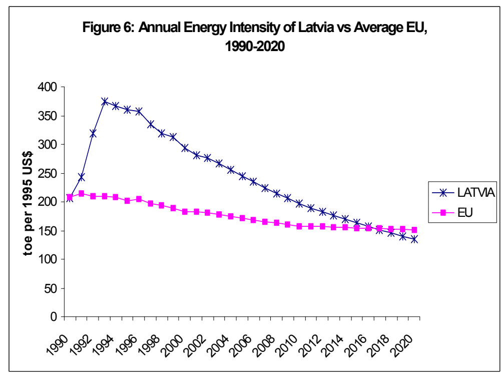


Figure 6: Annual Energy Intensity of Latvia vs Average EU, 1990-2020

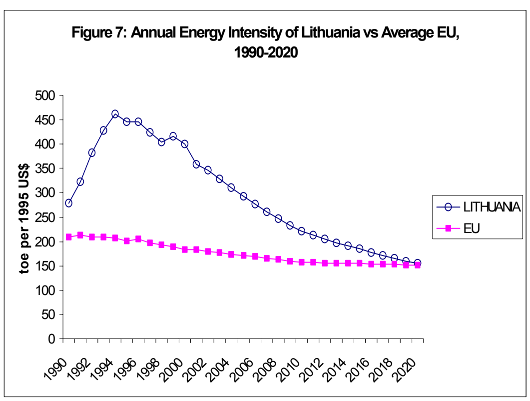


Figure 7: Annual Energy Intensity of Lithuania vs Average EU, 1990-2020

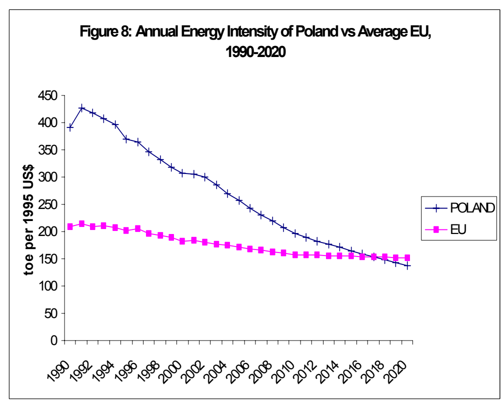


Figure 8: Annual Energy Intensity of Poland vs Average EU, 1990-2020

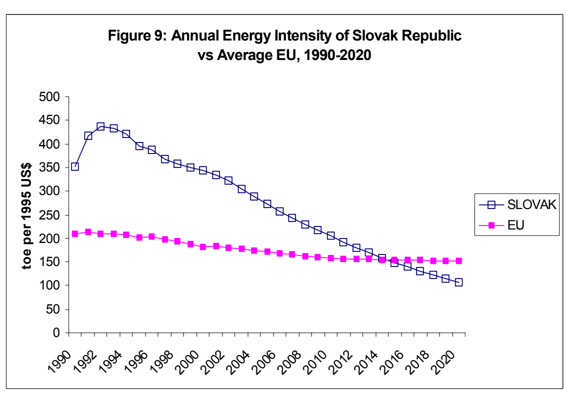


Figure 9: Annual Energy Intensity of Slovak Republic vs Average EU, 1990-2020

6. Conclusions

This paper has investigated the relationship between energy intensity in the 11 countries of Eastern Europe that can broadly be considered as in transition to a full market economy, and that of the present EU members. It begins by noting that in terms of *per capita* growth there is evidence of convergence between these countries and the EU15 average. The rate at which the two converge is estimated at about 0.3 percent *per annum* over the period 1990- to 2001.

The existence of convergence in terms of *per capita income* is no guarantee of convergence in terms of energy intensity. A casual look at the data on the latter shows some evidence of convergence, and a carefully estimated econometric model of lagged adjustment confirms these findings. The data show that, on average, a one per cent decrease in the *per capita* income gap between developed and transition economies leads to a decrease in the energy intensity growth rate of a transition country by 0.7%. There are differences in the rate of convergence across countries, and these depend on two parameters that are allowed to vary across countries: the elasticity of desired energy intensity with respect to the per capita income gap (the parameter η in the paper) and the rate at which actual energy intensity adjusts to the desired energy intensity (the parameter μ in the paper). The first parameter is statistically significant for 6 countries of the 12 countries (Hungary, Romania, Czech Republic, Bulgaria, Croatia and Turkey), and the second is statistically significant for 8 of the 12 countries (all except Hungary, Slovenia and Lithuania). The fastest converging countries according to these parameters are the Czech Republic, Bulgaria, Croatia and Turkey.

Although the parameters η and μ are not significant for all countries, we can still estimate the forecast energy intensity for 7 of them for which forecast values of

GDP growth are available to 2020: Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland and Slovak Republic). This involves using the full estimation equation in which all the countries dummies, as well as period and slope dummies, are included. While not all the dummy variables are individually significant, an F-test shows they are collectively significant. The results show that, over the period to 2020, we can expect energy intensities to converge to EU levels significantly for six of the seven countries – i.e., all except Estonia. We also estimate the actual level of energy demand in each of these countries and find that, between 2000 and 2020 energy demand will **increase in all 7 countries** in spite of the major decline in energy intensity. Thus it will not be feasible to use as a target a non-increasing level of total energy consumption.

Further work should look at the reasons behind these results. Why do some countries exhibit higher rates of convergence than others? This will require a meta type analysis of the parameters η and μ. The amount of data available for this purpose is rather limited and so using econometric methods will not be feasible, but this should not prevent less formal methods being used. Possible variables to include would be indicators of reform in the areas of energy pricing etc., that the EBRD has been collecting over the last decade.

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Annex 1
Raw Data

Annex Table 1: Total primary energy supply (TPES) in Mtoe.

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Transition Countries												
Bulgaria	28.82	22.63	21.03	22.42	21.63	23.53	23.2	20.86	20.12	18.2	18.78	19.5
Croatia	9.69	7.61	6.71	6.9	6.94	7.12	7.24	7.8	8.08	8.03	7.78	7.9
Czech	47.4	42.92	43.19	41.88	40.38	41.38	42.6	42.4	41.05	38.24	40.38	41.4
Estonia	7.23	6.5	6.27	4.95	5.18	4.81	5.28	5.17	4.95	4.63	4.52	4.7
Hungary	28.44	27.32	24.97	25.54	24.81	25.53	25.97	25.41	25.26	25.2	24.78	25.3
Latvia	7.98	6.26	5.98	4.93	4.57	3.99	4.16	4.41	4.27	3.84	3.66	4.3
Lithuania	16.89	17.6	11.94	9.21	8.31	8.98	9.57	9.08	9.49	8.26	7.72	8
Poland	99.85	98.48	97.31	101.31	96.73	99.87	107.48	103.42	97.45	93.48	89.98	90.1
Romania	62.4	51.48	47.39	45.63	42.92	46.41	49.89	44.72	40.72	36.44	36.33	36.8
Slovak	21.68	19.7	18.22	17.71	17.1	17.75	17.82	17.76	17.34	17.37	17.47	18.7
Slovenia	6.05	5.7	5.01	5.3	5.55	5.96	6.27	6.63	6.51	6.39	6.54	6.8
Turkey	52.65	52.14	53.59	56.84	56.04	61.4	66.87	70.47	71.69	70.54	77.1	72.46
EU Member Countries												
Austria	25.22	26.5	25.09	25.77	25.74	26.36	27.72	28.1	28.32	28.57	28.58	30.72
Belgium	48.43	51.44	52.02	50.81	51.94	52.4	56.43	57.1	58.35	58.55	59.22	59.00
Denmark	18.07	20.32	19.46	20.18	20.55	20.29	22.57	21.02	20.8	19.97	19.46	19.78
Finland	28.81	29.35	27.58	28.88	30.83	29.26	32.09	33.06	33.46	33.35	33.15	33.82
France	226.03	238.63	234.5	238.89	230.81	239.9	252.66	246	254.41	255.17	257.13	265.57
Germany	355.53	347.37	341.07	338.04	336.3	339.87	351.29	347.3	344.7	341.05	339.64	351.09
Greece	21.75	21.85	22.4	22.2	22.97	23.13	24.16	25.05	26.38	26.62	27.82	28.70
Ireland	10.46	10.49	10.39	10.77	11.28	11.35	11.93	12.53	13.26	13.94	14.62	14.98
Italy	151.63	155.9	155.45	153.56	151.83	159.82	159.26	161.54	166.01	169.02	171.57	172.00
Luxembourg	3.57	3.81	3.83	3.88	3.8	3.38	3.44	3.4	3.32	3.49	3.68	3.83
Netherlands	66.47	70	69.34	69.98	70.46	73.17	75.78	74.76	74.26	74.55	75.8	77.21
Portugal	17.16	17.3	18.56	18.22	18.76	19.99	19.88	20.89	22.63	24.34	24.61	24.73

Annex Table 1: Total primary energy supply (TPES) in Mtoe, continued.

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
EU Member Countries												
Spain	90.53	94.27	96.57	93.47	98.16	103.12	101.46	107.56	112.78	118.46	124.88	127.38
Sweden	46.67	48.19	46.02	46.07	49.36	49.92	51.02	49.68	50.71	50.48	47.78	51.05
UK	212.41	218.75	218.41	220.82	227.05	224.27	232.97	226.87	230.13	231.24	232.64	235.16

Source: IEA (1999a,b; 2000a,b); Statistics Lithuania (1995; 1996); Statistical Office of Estonia (1998); Central Statistical Bureau of Latvia (1996); Ministry for Economic Activities of Slovenia (1994); Ministry of Economy of Croatia (1994, 1995).

Annex Table 2: Gross domestic production in Billion 1995 US$ (PPP).

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Transition Countries												
Bulgaria	53.60	49.10	45.50	44.80	45.60	46.90	42.20	39.20	40.60	41.60	44.00	51.42
Croatia	36.85	29.76	26.30	24.20	25.60	27.30	28.90	30.90	31.70	31.60	32.70	36.10
Czech	134.06	118.49	117.89	117.96	120.58	127.74	133.23	132.21	130.62	130.12	133.94	140.10
Estonia	13.93	12.79	10.10	9.30	9.10	9.50	9.80	10.90	11.40	11.30	12.00	12.10
Hungary	104.51	92.07	89.25	88.74	91.35	92.71	93.96	98.25	103.03	107.32	112.93	117.20
Latvia	25.11	22.50	14.70	12.50	12.60	12.50	12.90	14.00	14.50	14.70	15.70	16.80
Lithuania	35.40	33.41	26.40	22.10	19.90	20.60	21.50	23.10	24.30	23.30	24.20	26.80
Poland	243.31	226.24	231.93	240.60	253.16	270.95	287.28	306.89	321.76	334.79	348.35	351.70
Romania	162.70	141.50	129.20	131.10	136.30	146.00	151.80	142.60	135.70	132.60	134.80	120.10
Slovak	50.46	43.10	40.22	40.99	43.00	45.90	48.75	51.77	53.89	54.92	56.13	59.50
Slovenia	26.61	24.24	22.90	23.60	24.80	25.80	26.70	28.00	29.00	30.60	32.00	31.00
Turkey	296.75	299.50	317.42	342.95	324.24	347.56	371.91	399.90	412.27	392.85	420.95	390.60
EU Member Countries												
Austria	155.98	161.16	164.87	165.56	169.87	172.63	176.09	178.89	185.19	190.39	196.02	199.10
Belgium	206.89	210.57	213.88	210.73	216.54	222.13	224.79	232.81	238.04	245.23	255.11	256.00
Denmark	108.82	110.04	110.71	110.71	116.76	119.97	122.99	126.65	130.13	132.91	137.17	138.10
Finland	99.63	93.39	90.29	89.25	92.78	96.32	100.18	106.48	112.16	116.67	123.32	124.70
France	1138.29	1149.63	1166.78	1156.43	1180.32	1200.03	1213.27	1236.38	1278.43	1315.72	1356.48	1394.50
Germany	1614.17	1660.02	1697.23	1678.78	1718.17	1747.84	1761.23	1785.84	1820.77	1854.4	1910.12	1922.00

Annex Table 2: Gross domestic production in Billion 1995 US$ (PPP), continued.

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
EU Member Countries												
Greece	126.05	129.96	130.87	128.78	131.35	134.11	137.27	142.26	147.05	152.09	158.64	165.20
Ireland	51.97	52.97	54.75	56.22	59.46	65.39	70.46	78.09	84.81	94.02	104.79	110.10
Italy	1082.29	1097.34	1105.68	1095.91	1120.1	1152.85	1165.45	1189.07	1210.6	1230.12	1265.97	1287.40
Luxembourg	10.52	11.17	11.67	12.69	13.22	13.72	14.21	15.49	16.4	17.38	18.68	19.20
Netherlands	295.78	303.16	308.31	311.05	319.11	328.51	338.49	351.48	366.77	380.38	393.57	399.00
Portugal	125.06	130.52	131.95	129.25	130.5	136.06	141.29	146.86	153.5	158.7	164.11	166.80
Spain	558.22	570.88	574.8	568.12	580.9	596.69	611.23	635.84	663.41	690.81	719.11	739.50
Sweden	171.03	169.14	166.19	163.14	169.85	176.12	178.02	181.7	188.22	196.7	203.8	215.50
UK	1008.04	994.15	996.41	1021.24	1068.82	1099.81	1128.66	1167.55	1202.46	1228.02	1263.39	1293.50

Source: IEA (1999a,b; 2000a,b); Statistics Lithuania (1995; 1996); Statistical Office of Estonia (1998); Central Statistical Bureau of Latvia (1996); Ministry for Economic Activities of Slovenia (1994); Ministry of Economy of Croatia (1994, 1995).

Annex Table 3: Population (million).

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Transition Countries												
Bulgaria	8.70	8.60	8.50	8.50	8.40	8.40	8.40	8.30	8.30	8.20	8.20	8.00
Croatia	4.80	4.80	4.80	4.80	4.80	4.60	4.50	4.40	4.40	4.40	4.40	4.40
Czech	10.36	10.31	10.32	10.33	10.33	10.33	10.32	10.30	10.29	10.29	10.27	10.30
Estonia	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.40	1.40	1.40	1.40	1.40
Hungary	10.37	10.35	10.32	10.29	10.26	10.23	10.19	10.16	10.14	10.07	10.02	10.20
Latvia	2.67	2.66	2.63	2.59	2.50	2.50	2.50	2.50	2.40	2.40	2.40	2.40
Lithuania	3.72	3.74	3.74	3.73	3.72	3.72	3.71	3.71	3.70	3.70	3.70	3.50
Poland	38.12	38.25	38.37	38.46	38.54	38.59	38.62	38.65	38.67	38.65	38.65	38.60
Romania	23.20	23.20	22.80	22.80	22.70	22.70	22.60	22.60	22.50	22.50	22.40	22.40
Slovak	5.30	5.28	5.31	5.33	5.35	5.36	5.37	5.38	5.39	5.40	5.40	5.40
Slovenia	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
Turkey	56.20	57.31	58.40	59.49	60.57	61.65	62.70	63.75	64.79	65.82	66.84	68.61

Annex Table 3: Population (million), continued.

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
EU Member Countries												
Austria	7.72	7.8	7.91	7.99	8.03	8.05	8.06	8.07	8.08	8.09	8.11	8.13
Belgium	9.97	10.01	10.05	10.09	10.12	10.14	10.16	10.18	10.2	10.22	10.25	10.29
Denmark	5.14	5.15	5.17	5.19	5.2	5.22	5.26	5.28	5.3	5.32	5.34	5.36
Finland	4.99	5.01	5.04	5.07	5.09	5.11	5.13	5.14	5.15	5.17	5.18	5.19
France	58.03	58.32	58.61	58.9	59.12	59.33	59.53	59.74	59.94	60.16	60.43	60.90
Germany	79.36	79.98	80.59	81.18	81.42	81.66	81.9	82.05	82.03	82.09	82.17	82.33
Greece	10.16	10.25	10.32	10.38	10.43	10.45	10.48	10.5	10.52	10.53	10.56	10.59
Ireland	3.51	3.53	3.56	3.57	3.59	3.6	3.63	3.66	3.71	3.75	3.79	3.90
Italy	56.72	56.75	56.86	57.05	57.2	57.3	57.4	57.51	57.59	57.65	57.73	57.90
Luxembourg	0.38	0.39	0.39	0.4	0.4	0.41	0.42	0.42	0.43	0.44	0.44	0.44
Netherlands	14.95	15.07	15.18	15.29	15.38	15.46	15.53	15.61	15.7	15.81	15.92	16.04
Portugal	9.9	9.87	9.87	9.88	9.9	9.92	9.93	9.94	9.97	9.99	10.01	10.10
Spain	38.85	38.92	39.01	39.09	39.15	39.22	39.28	39.35	39.45	39.63	39.93	40.30
Sweden	8.57	8.62	8.67	8.72	8.78	8.83	8.84	8.85	8.85	8.86	8.87	8.89
UK	57.56	57.81	58.01	58.2	58.4	58.61	58.81	59.01	59.24	59.5	59.76	58.80

Source: IEA (1999a, 1999b, 2000a, 2000b); Statistics Lithuania (1995; 1996); Statistical Office of Estonia (1998); Central Statistical Bureau of Latvia (1996); Ministry for Economic Activities of Slovenia (1994); Ministry of Economy of Croatia (1994, 1995).

Annex 2
Annual Total Primary Energy Demand in Transition Countries and the EU (on average), Mtoe, 1990-2020.

Year	Czech	Estonia	Hungary	Latvia	Lithuania	Poland	Slovak	*Average EU*
1990	40.75	5.38	25.84	5.17	9.85	95.12	17.77	93.96
1991	41.22	5.63	25.98	5.46	10.76	96.75	17.95	97.56
1992	40.77	5.20	25.65	4.69	10.11	97.04	17.60	96.57
1993	40.95	5.24	25.41	4.69	9.45	97.86	17.75	96.55
1994	41.50	5.16	25.95	4.61	9.18	100.56	18.12	98.13
1995	41.45	5.22	25.58	4.51	9.19	100.29	18.10	97.37
1996	42.93	5.34	26.40	4.60	9.61	104.41	18.89	100.67
1997	42.55	5.24	26.57	4.69	9.78	106.13	19.01	99.52
1998	42.76	5.26	26.85	4.62	9.81	106.88	19.23	100.53
1999	42.71	5.20	26.88	4.61	9.72	106.69	19.23	100.67
2000	42.68	5.25	27.04	4.62	9.71	106.86	19.34	100.65
2001	44.14	5.29	27.87	4.71	9.60	107.66	19.92	102.97
2002	45.07	5.44	28.42	4.90	9.93	112.07	20.58	103.69
2003	45.55	5.49	28.60	4.96	10.07	113.67	20.94	104.42
2004	45.98	5.52	28.73	5.01	10.18	114.88	21.26	105.15
2005	46.40	5.55	28.85	5.05	10.30	116.05	21.58	105.89
2006	46.82	5.58	28.97	5.09	10.41	117.23	21.90	106.63
2007	47.25	5.61	29.09	5.14	10.52	118.41	22.23	107.37
2008	47.68	5.64	29.21	5.18	10.64	119.61	22.56	108.12
2009	48.12	5.67	29.33	5.23	10.76	120.82	22.90	108.88
2010	48.56	5.70	29.45	5.27	10.88	122.04	23.24	109.64
2011	49.40	5.75	29.74	5.36	11.06	123.90	23.86	111.18
2012	50.30	5.82	30.09	5.45	11.28	126.04	24.47	112.74
2013	51.21	5.88	30.45	5.55	11.51	128.26	25.10	114.31
2014	52.15	5.94	30.81	5.65	11.74	130.53	25.74	115.91
2015	53.10	6.01	31.19	5.75	11.98	132.83	26.39	117.54
2016	54.07	6.08	31.56	5.85	12.23	135.18	27.07	119.18
2017	55.05	6.15	31.94	5.95	12.47	137.57	27.76	120.85
2018	56.06	6.21	32.33	6.06	12.73	140.00	28.46	122.54
2019	57.08	6.28	32.71	6.17	12.98	142.47	29.19	124.26
2020	58.12	6.35	33.11	6.27	13.25	144.99	29.93	126.00
Average annual growth rate (2000-2020)	1.81%	1.05%	1.12%	1.79%	1.82%	1.78%	2.74%	1.26%

Table 1: Energy intensity and GDP per capita, transition countries and *average EU*.

Country	Energy intensity (toe per 95US$)			GDP per capita ('000 95US$ per capita)		
	1992	2001	% Change 1992-2001	1992	2001	% Change 1992-2001
Bulgaria	462	379	-18.0%	5	6	20.1%
Croatia	255	219	-14.2%	5	8	49.7%
Czech republic	366	296	-19.3%	11	14	19.1%
Estonia	621	388	-37.4%	7	9	28.4%
Hungary	280	216	-22.8%	9	11	32.9%
Latvia	407	256	-37.1%	6	7	25.2%
Lithuania	452	299	-34.0%	7	8	8.5%
Poland	420	256	-38.9%	6	9	50.7%
Romania	367	306	-16.5%	6	5	-5.4%
Slovak republic	453	314	-30.6%	8	11	45.5%
Slovenia	219	219	0.3%	11	16	35.4%
Turkey	169	186	9.9%	5	6	4.7%
Average EU	209	183	-12.4%	19	24	26.8%

Table 2: Regression results, β-convergence in real per capita GDP.

Variable	Coefficient	Std. Error*	t-Statistic	Prob.
Intercept	0.9650	0.2129	4.5318	0.0000
$\ln(y_{i,t-1})$	-0.3046	0.0684	-4.4537	0.0000

R-squared 0.5297
Adjusted R-squared 0.4625
*White Heteroskedasticity-Consistent Standard Errors & Covariance

Table 3: Regression Results: Two-Way Fixed Effects

Variable	Coefficient	Std. Error	t-Statistic	Prob.
Intercept	-4.480	1.150	-3.894	0.000
X1	0.715	0.261	2.740	0.007
X2	1.559	0.400	3.898	0.000
CS1	2.558	0.795	3.218	0.002
CS2	0.533	0.976	0.546	0.587
CS3	3.294	0.860	3.831	0.000
CS4	4.559	1.131	4.029	0.000
CS5	3.172	0.680	4.664	0.000
CS6	3.447	1.220	2.827	0.006
CS7	5.104	1.215	4.202	0.000
CS8	5.919	1.418	4.175	0.000
CS9	3.006	0.885	3.397	0.001
CS10	2.374	1.747	1.358	0.178
CS11	1.726	0.878	1.966	0.053
CS1X1	-0.082	0.382	-0.215	0.831
CS1X2	-0.723	0.312	-2.316	0.023
CS2X1	0.057	0.441	0.130	0.897

CS2X2	-0.073	0.372	-0.195	0.846
CS3X1	0.089	0.507	0.175	0.862
CS3X2	-0.899	0.252	-3.568	0.001
CS4X1	0.336	0.340	0.990	0.325
CS4X2	-1.295	0.360	-3.599	0.001
CS5X1	0.498	0.374	1.330	0.187
CS5X2	-0.953	0.254	-3.748	0.000
CS6X1	0.161	0.431	0.372	0.711
CS6X2	-1.097	0.408	-2.689	0.009
CS7X1	0.314	0.408	0.768	0.445
CS7X2	-1.586	0.375	-4.228	0.000
CS8X1	0.223	0.395	0.566	0.573
CS8X2	-1.982	0.483	-4.100	0.000
CS9X1	0.199	0.402	0.496	0.621
CS9X2	-0.916	0.298	-3.073	0.003
CS10X1	-0.146	0.466	-0.313	0.755
CS10X2	-0.635	0.612	-1.038	0.302
CS11X1	-0.925	0.385	-2.399	0.019
CS11X2	-0.277	0.423	-0.655	0.514
TS1	0.285	0.108	2.632	0.010
TS2	0.281	0.120	2.349	0.021
TS3	0.271	0.100	2.695	0.008
TS4	0.217	0.088	2.469	0.016
TS5	0.224	0.079	2.832	0.006
TS6	0.219	0.072	3.062	0.003
TS7	0.171	0.066	2.597	0.011

*White Heteroskedasticity consistent standard errors and covariance
R^2 0.5702
Adjusted R^2 0.3452
F-test on slope dummy variables: F-statistic = 3.658; Probability = 0.000

Table 4: Estimates of adjustment parameter, by country

Country	$\hat{\eta}_i$	Standard Error	t-statistic	Confidence interval at 20% level of significance
Bulgaria	1.32	0.51	2.60	1.32 ± 1.3 *0.51 = (0.66, 1.98)
Croatia	1.93	0.87	2.21	1.93 ± 1.3*0.87 = (0.80, 3.06)
Czech Republic	0.82	0.30	2.71	0.82 ± 1.3*0.30 = (0.43, 1.21)
Hungary	0.50	0.30	1.69	0.50 ± 1.3*0.30 = (0.11, 0.89)
Romania	0.70	0.28	2.50	0.70 ± 1.3*0.28 = (0.34, 1.06)
Turkey	2.18	1.41	1.55	2.18 ± 1.3*1.41 = (0.35, 4.01)

Table 5: Estimates of $\hat{\mu}_i$, by country

Country	$\hat{\mu}_i$	Median Lag (years)	Standard Error	t-statistic	Confidence Interval at 20% Significance Level
Bulgaria	0.63	0.7	0.27	2.37	0.63 ± 1.30*0.27 = (0.28, 0.98)
Croatia	0.77	0.5	0.32	2.45	0.77 ± 1.30*0.32 = (0.35, 1.19)
Czech Rep	0.80	0.4	0.40	2.02	0.80 ± 1.30*0.40 = (0.28, 1.32)
Estonia	1.05	n.a.	0.23	4.66	1.05 ± 1.30*0.23 = (0.75, 1.35)
Hungary	1.21	n.a.	0.26	4.60	1.21 ± 1.30*0.26 = (0.87, 1.55)
Latvia	0.88	0.3	0.33	2.67	0.88 ± 1.30*0.33 = (0.451, 1.31)
Lithuania	1.03	n.a	0.33	3.09	1.03 ± 1.30*0.33 = (0.60, 1.46)
Poland	0.94	0.3	0.28	3.38	0.94 ± 1.30*0.28 = (0.58, 1.30)
Romania	0.91	0.3	0.29	3.17	0.91 ± 1.30*0.29 = (0.53, 1.29)
Slovak Rep	0.57	0.8	0.37	1.54	0.57 ± 1.30*0.37 = (0.09, 1.05)
Turkey	0.71	0.6	0.26	2.74	0.71 ± 1.30*0.26 = (0.37, 1.05)

Table 6: Ranking of countries according to the speed of adjustment (from slowest to fastest)

$\hat{\eta}_i$ (pertaining to the rate at which income gap between *average EU* country and transition country *i* is eliminated in one year)	$\hat{\mu}_i$ (pertaining to the rate at which the difference between the desired and actual energy intensity in transition country *i* is eliminated in one year)
1. Hungary	1. Slovak Republic
2. Romania	2. Bulgaria
3. Czech Republic	3. Turkey
4. Bulgaria	4. Croatia
5. Croatia	5. Czech
6. Turkey	6. Latvia
	7. Romania
	8. Poland

Note: Countries listed are those whose speeds of adjustment are found to be statistically significant at 20% level. In the second column, the listed countries are only those whose parameter estimate lies between zero and one.

Table 7: Average annual growth rates (%) of the focus countries

Country	GDP		Population		Energy cons.	
	2000 to 2010	2011 to 2020	2000 to 2010	2011 to 2020	2000 to 2010	2011 to 2020
Czech Republic	5.20	5.50	-0.02	-0.10	-	-
Estonia	3.60	2.60	-0.20	-0.44	-	-
Hungary	4.00	3.00	-0.40	-0.40	-	-
Latvia	5.30	5.70	-0.10	-0.20	-	-
Lithuania	7.00	5.70	-0.10	0.10	-	-
Poland	6.50	5.40	-0.12	-0.15	-	-
Slovak	7.41	9.40	0.30	0.10	-	-
EU	2.40	1.80	0.20	0.03	0.70	1.40

Sources : Hungary - UNEP (1999); Lithuania – Ministry of Economy (2002); Czech, Estonia, Latvia, Poland and Slovak - UNFCCC National Communications (2001).

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[44] If the elasticity of energy with respect to GDP is γ in developing countries and β in developed countries, and if the GDP growth rate of π in the developing countries and ρ in the developed countries, the rate of convergence in energy intensity is given by: $[(\beta-1)\ \rho - (\gamma - 1)\ \pi]$. Hence if $\gamma = \beta < 1$, convergence requires that $\pi > \rho$. If, however, $\gamma < \beta$ convergence may not take place even if $\pi > \rho$. With γ and β time variant, the analysis becomes more complex, but the basic point remains valid.

[5] Other studies (Sala-i, 1996; Kaitila, 2004) looked at income convergence rates of individual country groups. This study, however, exploits the information of the EU and transition countries as one whole dataset, which allows for estimating the convergence rate of the transition countries with respect to the EU.

[6] Definition. *International marine bunkers* cover those quantities delivered to sea-going ships of all flags, including warships. Consumption by ships engaged in transport in inland and coastal waters is not included. *Stock changes* reflect the difference between opening stock levels at the first day of the year and closing levels on the last day of the year of stocks on national territory held by producers, importers, energy transformation industries and large consumers. A stock build is shown as a negative number, and a stock draw as a positive number (IEA, 1999/2000).

[7] It is curious to note that there is something of an inverse relationship between μ and η. We have no explanation for this.

[8] Slovenia was excluded because its $\hat{\eta}_i$ is absurdly huge compared to those of the other countries.

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(lxiii) This paper was presented at the ENGIME Workshop on “Social dynamics and conflicts in multicultural cities”, Milan, March 20-21, 2003
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