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A Note on Growth, Energy Intensity and the Energy Mix: A Dynamic Panel Data Analysis[1]

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Abstract: This paper explores how changes in energy intensity and the switch to renewables can boost economic growth. In doing so, we implement a dynamic panel data approach on a sample of 134 countries over the period 1960 to 2010. We incorporate a set of control variables, related to human and physical capital, socio-economic conditions, and policies which are widely used in the associated literature. According to our results, and given the current state of technology, improving energy intensity is an approach that could reconcile growth and the environment at the worldwide level. Moving to conventional renewables (biomass and hydro) may reduce CO2 emissions, consistent with the related literature, although we do not find evidence that supports a growth enhancing effect. However, moving to frontier renewables (wind, solar, wave or geothermic) does reconcile the reduction of CO2 emissions with economic growth. Our results are robust to the specification of the dynamic panel with respect to three alternative methods, namely, the pooled OLS regression, the regression under fixed effects, and the GMM estimation.

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1.- Introduction

Sustainability requires economic growth to be compatible with the social and environmental targets that are key for long term development (World Bank, 2012; United Nations, 2015). Reducing energy intensity and switching to renewables have been proved to be viable options to reducing CO2 emissions, for particular levels of development (Ang, 2007; 2008; Marrero, 2010; Apergis, *et al*., 2010).[3] In this paper, we explore the links between economic growth and these two key energy dimensions at the worldwide level (see Ucan *et al*., 2014, and the references therein, for a recent survey about the links between energy and economic growth). We aim to quantify the extent to which a reduction in energy intensity and/or a movement to renewables can be reconciled with higher GDP per capita growth. Therefore, could energy intensity reductions and the switch to renewables help curb down CO2 emissions and foster economic growth simultaneously?

A large body of research has analyzed the compatibility between economic growth and social targets, finding that the links between growth and social pillars are self-reinforcing in most cases. For instance, achievements such as reducing poverty (Ravallion, 2012), higher equality of opportunities (Marrero and Rodríguez, 2013), lower social conflict (Alesina et al., 1996), or higher political stability (Menegaki and Ozturk, 2013), are all factors that enhance growth. However, results are not that robust when the causal nexus between growth and the environment comes into force. On the one hand, steady-state growth seems compatible with substantial reductions in local pollutants emissions (i.e., those pollutants related to local air quality and consequences on human health, such as CO, NOx, or sulfurs). On the other hand, for global pollutants such as CO2, the evidence that emissions first go up and later go

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[3] More recently, Díaz et al. (2018) analyze this relationship worldwide, Wang (2013) does for China and the US, and Alvarez-Herranz et al. (2017), analyzes OECD countries, emphasizing the role of energy innovation. Apergis et al. (2010) also conclude that nuclear energy consumption plays an important role in curbing CO2 emissions in the short term.

down, in a growing economy, is not robust according to the literature related to the Environmental Kuznets Curve (EKC).[4]

Existing literature mostly builds the link between the economy and CO2 emissions by considering energy factors. In this sense, Śmiech and Papież (2014) report evidence of different patterns of causality, depending on countries' degrees of compliance with the EU energy policy targets, leading to the conclusion that the higher the reduction in energy intensity and the higher the share of renewable energy consumption over total energy consumption, the greater the reduction of global emissions. In parallel, several authors have emphasized the importance of the complementarity between capital and energy in the production technology. For instance, Atkeson and Kehoe (1999), and Díaz and Puch (2004) make early attempts at understanding the mechanisms behind the small short-term substitution between capital and energy and their consequences on production. Their results support the finding that big differences in energy prices across countries do not imply a substantial gap in macroeconomic performance. The reason is that the production technology embodies channels that adjust energy price shocks in the medium run, fundamentally through investment in new, more energy efficient capital. For instance, the capital replacement mechanism in Schumpeterian growth models helps to reconcile long-run growth with large movements in energy prices as in Ferraro and Peretto (2017). More recently, Díaz and Puch (2016) and Rausch and Schwerin (2017) have incorporated technological progress into various aggregate models with imperfect substitution between energy and capital. We take these theoretical frameworks as tools that help to interpret our findings, as we show in the Section of results.

While the positive effect of reducing energy intensity and moving to renewables on global emissions is a well-established result in the literature, the impact of both of these energy variables on growth deserves further exploration and simultaneous. For

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[4] For local pollutants with visible damage on health, the applicability of the policies at the local level has led policy makers to implement abatement policies very quickly (Alvarez et al., 2005; Brock and Taylor, 2010). On the other hand, the relationship between global emissions and economic growth has been extensively analyzed and the conclusions, in most cases, have found that the evidence of an EKC is weak (see Kijima et al., 2010, and Bölük and Mert 2014, and the references therein), especially when we look at the worldwide level.

instance, while Inglesi-Lotz (2016), Bhattacharya et al. (2016, 2017) or Narayan and Doytch (2017), find a positive impact of renewables on growth, they do not account for energy intensity in their regression. This omission could negate or at least skew their results that found there was a link between renewables and growth because of the existing correlation between energy intensity and the share of renewables (i.e., due to common environmental legislation or common technological progress).[5] Moreover, many of these studies produce results that differ significantly depending on the period, the set of countries, the variables included, or the method of analysis. These variations could be due to the state of technology in each setting. As technological progress makes renewable sources cheaper, the operating costs of these energy sources will actually decline, implying that their use become more appealing to boost growth and reduce CO2 emissions.

Thus, as stated above, our main goal is to analyze, on a global scale, the robustness of how changes in energy intensity, together with the changes in the share of renewables in primary consumption, might affect growth. Our final goal is to disentangle whether we can conclude that these energy factors are among the key drivers, thus making the link between growth and environmentally friendly energy to be self-reinforcing.

To achieve this goal, we construct a data set that combines economic, energy and other macroeconomic information for a total of 134 countries from 1960 through 2010. Then, we specify and estimate a reduced form growth model, in the spirit of Barro (2000) and Forbes (2000), but augmented with energy variables (Marrero, 2010). The energy variables are energy intensity, the primary energy mix (which distinguishes between fossil fuels, renewables sources and nuclear plants), and the final energy mix (which includes industry, transport, services, agriculture and the residential sector). In addition to the energy variables, we also consider alternative macroeconomic variables

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[5] Another controversy in this literature is found in the direction of causality. For instance, Apergis and Payne (2010a, 2010b) report evidence for bidirectional Granger-causality between renewable energy consumption and economic growth in both the short-and long term in OECD countries over the period 1985–2005, and in Eurasian countries over the period 1992–2007, respectively. However, Ucan et al. (2014) provide empirical evidence in favor of the unidirectional causality of renewable energy consumption on GDP for 15 EU countries over the period 1990-2011. In this paper, we are interested in the causality of renewables on economic growth.

widely used in the growth literature (the price of investment, educational attainment, fertility rates, government size, trade openness, or inflation), to explore the sensitivity of our growth-energy results to the specific choice of control variables.

We set-up a dynamic panel data (DPD) model and estimate it using three alternative methods: i) a pooled panel regression estimated by ordinary least squares; ii) a fixed effect dynamic panel, in order to check whether our results could be biased by the pool of data; and iii) a dynamic model estimated by the system GMM approach (Blundell and Bond, 1998; Roodman, 2009) to try to overcome potential endogeneity issues, given the double-sense causality usually found between energy and GDP growth (Atems and Hotaling, 2018). In general, we find that our main results are robust to the econometric method and to the model specification considered.

We find the following. First, improvements in energy intensity favor the opportunities for per capita GDP growth, regardless of the control variables included in the regressions and the econometric approach used. This result is consistent with the literature. On average (taking into consideration all estimated models), a one percent decrease in energy intensity is associated with a higher GDP per capita annual growth of between 0.5 and 1.0 percent, depending on the model specification.

Secondly, with respect to the primary energy consumption, the higher the share of renewable energy sources, the lower the growth rate, regardless of the level of income. Those countries showing an annual increase of 1 p.p. in the share of renewables (with respect to the share of fossil fuels) show, on average, a lower per capita GDP growth of about -0.4 and -1.2 p.p., depending on the model. However, when we distinguish between conventional renewables (hydro and biomass) and “frontier” renewables (wind, solar, wave or geothermic), we find that moving from fossil fuels to conventional renewables can be related to lower growth, but, instead, if the switch tends towards “frontier” renewables, our results show a positive association with growth, with an estimated elasticity of between 0.4 and 0.6.

Thirdly, with respect to the composition of the final energy demanded, represented by the fraction of final energy consumption consumed by a given sector, we find that only the share of residential consumption has a negative impact, once variables such as energy intensity, the degree of development of the countries, and their primary energy mix, are controlled for in the regression analysis. Our estimates hover around 0.6 and 1.2, that is, those countries showing an annual increase of 1 p.p. of the share of the residential sector (with respect to the agriculture, as explained in the next section) show, on average, a lower per capita GDP growth of about - 0.6 and -1.2 p.p. This finding implies that neither the growing importance of services, mainly observed in developed countries, nor the increasing role of industry in countries such as China or India, nor the variable role of the primary sector in practically all countries, seem to be related with higher economic growth.

The rest of the paper is organized as follows. Section 2 describes the reduced form growth regression extended with energy variables. Section 3 describes the data set and the main characteristics of the different sets of control variables. Section 4 discusses the econometrics implemented and shows the estimation results of the growth-energy model. Finally, in view of the findings and under the lens of our model, Section 5 concludes and introduces some possible energy policy prescriptions.

2.- A growth-energy dynamic panel data model

We first introduce a reduced form specification model relating economic growth with energy variables, as well as a set of macroeconomic control variables widely used in the growth literature. The reduced form is derived from a Neoclassical growth model which has been extended to include energy use and the energy mix (Marrero, 2010; Díaz et al., 2018), leading to the following dynamic panel data model:

$$GY_{i,t} = \alpha + R_i + T_t + \beta \ln\left(\mathrm{Y}_{\mathrm{i,t-1}}\right) + \theta' XE_{i,t} + \lambda' X_{i,t} + \varepsilon_{i,t}. \qquad (1)$$

In this specification, the dependent variable $GY_{i,t}$ denotes per capita annual growth across the entire period (5 years, in our case) for country i and year t; R_i and T_t are country- and time-specific effects. In order to control for initial technology and conditional convergence, the per capita real GDP (in logs) at the beginning of the period, $\ln(\mathrm{Y}_{\mathrm{i,t-1}})$ is included.

The term $\theta' XE_{i,t}$ encompasses the effect of a set of energy variables with the following structure:

$$\theta' XE_{i,t} \equiv \theta_0 \Delta EI_{i,t} + \sum_{j=1}^{J-1} \theta_j^m \Delta m_{j,i,t} + \sum_{k=1}^{K-1} \theta_k^s \Delta s_{k,i,t}. \qquad (2)$$

The first key term $\Delta EI_{i,t}$ denotes the annual growth rate of the energy intensity, defined as the ratio between total primary energy consumption and real GDP (in TOE per 1M US$). The second term, $\Delta m_{j,i,t}$, denotes the annual changes (in percentage points, p.p.) in the share of consumption of primary energy from the source j over total primary energy. We classify primary energy from source j following the IEA criterion: renewable, nuclear, and fossil fuels (coal, oil and gas). The final term in expression (2), $\Delta s_{k,i,t}$, denotes the annual changes (in p.p.) in the share of final consumption of energy in sector k over total final consumption. Sectors k are grouped into industry, transport, residential, service and agriculture. This set of variables attempts to control for the changes in the final use of energy in economic sectors. In this way, we consider the differential effects that a *primary* energy source, such as renewable, may have depending on the *final* sector, such as transport, in which it is employed.

In order to avoid multicollinearity in the estimation of (1), we omit fossil fuels from primary energy and agriculture from the final energy mix. Thus, the estimated coefficients are referenced with respect to these omitted categories. In this sense, θ_j^m accounts for the elasticity of economic growth with respect to a change of the share in the primary mix from source j (i.e., renewables and nuclear) relative to the fossil fuels, while θ_k^s accounts for the growth due to a change in the share of final energy consumption in the sector k (industry, transport, residential, service) from the agriculture sector.

The last component in equation (1), $X_{i,t}$, compiles a set of control variables influencing the heterogeneous pattern of economic growth across countries. This includes technology and policy factors (details are shown below). We opt for considering alternative specifications to explore the sensitivity of the growth-energy results to the choice of macroeconomic factors. In all cases, energy variables are introduced sequentially, in order to analyze their direct impact on growth alongside the indirect effects produced by other energy variables.

For all specifications of (1), the set of variables $\left(R_i, T_t, \ln\left(Y_{i,t-1}\right), \Delta EI_{i,t}\right)$ is always included, *i.e.*, regional and time dummies, the lagged per capita income, and the change in energy intensity that is part of expression (2). In addition, the rest of the energy variables in (2), are sequentially incorporated to the structure: first the primary shares $\left\{\Delta m_{j,i,t}\right\}_{j=1}^{J-1}$, and then the sector shares $\left\{\Delta s_{k,i,t}\right\}_{k=1}^{K-1}$. Bearing this sequential strategy in mind, we define three specifications, labeled as M1, M2 and M3.

In specification M1, also referred to as the *skeleton* model, no additional control is considered, i.e., $X_{i,t} = 0$ in (1). The second specification M2 adds controls from the empirical growth literature, as in Perotti (1996), Forbes (2000), and Knowles (2005). These authors consider a measure of market distortions, given by the price of investment goods relative to those of the U.S., and, as a measure of human capital, the rate of secondary education of the (male and female) populations. Finally, the third specification M3 considers standard policy indicators as control variables (in line with Barro, 2000): the inflation rate (GDP deflator) as an indicator of macroeconomic stability, the adjusted ratio of the country's volume of trade to the country's GDP as an indicator of the degree of openness of the economy, the ratio of public consumption to GDP as an indicator of the burden imposed by the government on the economy, and the fertility rate (number of births over population).

3.- Data description on economic growth and energy

Our final database consists of an unbalanced panel of non-overlapping five-year periods (as it is standard in the recent empirical growth literature), containing 915 country-year observations covering 134 countries and spanning over the years 1960-2010. Thus, lagged variables in (1) are then measured five years before, while growth rates and other variables are measured across the quinquennial span. This sample extensively spans a broad time period, as well as covering a highly heterogeneous sample of countries worldwide.[6] However, the final number of observations used in the estimation of each model could be reduced because of the availability of data for several control variables in the empirical specifications (i.e. the $X_{i,t}$ component in expression (1)).

From the Penn World Tables (PWT 8.1), we take a series of population measurements and real GDP (PPP adjusted in US$ 2005 prices), while energy data is retrieved from the International Energy Agency (2016). Energy is defined in tons of oil equivalent (TOE) and referred to as primary consumption. Renewable sources include energy generated through hydro and biomass (conventional renewables), plus wind, solar, geothermic and waves plants (frontier renewables). We also distinguish among final sectors of energy use, as previously mentioned: agriculture, industry, transport, residential, commerce and other services.

Other control variables included in (1) combine Barro and Lee's (2013) educational attainment data base and the World Development Indicators from the World Bank. The set of control variables includes, as indicated above, educational attainment (primary and secondary), investment prices, inflation, degree of trade openness, government size, and fertility rates. Regional dummies are also considered in the estimated models, and we follow the World Bank classification (see footnote 6).

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[6] Following the World Bank classification, our 915 observations can be classified according to their geographical location: 20 observations are from North America, 323 from Europe and Central Asia, 149 from Latin American and the Caribbean, 123 from the Middle East and North Africa, 143 from Sub-Saharan Africa, 42 from South Asia and 115 from East Asia and the Pacific.

Table 1 reports descriptive statistics (mean and standard deviation) for our benchmark sample of 915 observations and for the income and energy variables. We highlight the following aspects. *Firstly*, the table shows the wide range of countries we have in the sample, with an average per capita GDP of $14,889 per year, and with a huge dispersion around the mean (a standard deviation of $17,807 per year). In our sample, we have observations for Mozambique in 1995 or D.R. of the Congo in 2005, which reached a GDP per capita of $422.30 and $502.26, respectively, or Norway and Singapore in 2010, with $58,127 and $69,141, respectively.

The range of the growth rates is also very wide, with a mean of 2.27% and a standard deviation of 5.44%. We have observations with highly negative growth rates (for example, -15% for Zimbabwe in 2005) and highly positive growth rates (for example, +21% for Yemen in 2005). However, on average, per capita GDP has grown worldwide except for the low-income countries group. It is worth noting that these average growth rates increase with the level of income.

Regarding energy intensity, the mean of the sample is 202.1 TOE per 1M of US$, with a dispersion of 143.1. We observe strongly inefficient countries in terms of their use of energy, such as Luxembourg in 1975 or Turkmenistan in 2005, with energy intensities as high as 400 TOE, together with highly energy efficient countries, such as Switzerland in 1995 or Dominican Republic in 2010 with energy intensities clearly below 100 TOE.

With respect to the primary energy share, at the aggregate level, fossil fuel sources account for 70% of the production of energy, and renewable sources account for 27%. However, the share of fossil fuel sources increases with the level of income, at the expenses of lowering the share of renewable sources. The shares of nuclear plants also increase with income, although it barely represents a 1% in non-OECD high-income countries. Regarding the final consumption of energy, the residential sector is by far the most important one (32.5%), together with industry (26%), and transport services (23%). Regarding the level of countries' GDP per capita, differences may reflect different stages in development. For instance, the residential sector accounts for the bulk in final energy consumption in low-income countries. The role of this residential share decreases with income level. By contrast, this pattern is (more or less) increasing for industry, transport and services.

[INSERT TABLE 1 ABOUT HERE]

To illustrate the dispersion in the entire pool of data, Figure 1 confronts the main economic and energy variables. The top panel depicts the scatter between GDP per capita and energy intensity for the levels (left picture) and the growth rates (right). The scatter between GDP per capita and energy intensity shows the enormous diversity of both variables in the sample. Indeed, we observe a wide range of country-year observations with small energy intensity and an enormous variation in their degree of development (almost 400% difference in the most extreme cases). Thus, although the correlation for the levels of these variables is negative, its dispersion is very large. However, when looking at their annual growth rates, the relationship between GDP and energy intensity turns out to clearly be negative and highly significant. That is, improvements in the use of energy (reductions of energy intensity) are associated with higher economic growth rates.

The bottom panel depicts the scatter between GDP per capita and the share of renewables (left picture) and the annual changes (right). When looking at the correlation between GDP per capita and the share of renewables (bottom panels of Figure 1), the evidence is not that clear. While the correlation between the levels of GDP per capita and the share of renewables is negative (left picture), although weak, that of the GPD per capita growth and the change in the share of renewables is null (right picture). Actually, any reported evidence seems unclear and any results may be inferred. Therefore, in order to properly quantify the partial correlations between economic growth and the energy variables considered, we need to estimate the model (1) under alternative specifications.

[INSERT FIGURE 1 ABOUT HERE]

To sum up, the evidence supporting the relationship between economic growth and energy intensity growth seems clear. In this paper, we assess its strength worldwide. However, the energy mix profiles across countries seem to exhibit conflicting patterns. This observation leads to the specification of model (1) in order to properly identify the partial correlations between economic growth and the energy variables. For this purpose, it is important to test for common slopes worldwide through a set of benchmark technology and policy control variables.

4.- Estimation results

We now analyze our estimates. First, we comment on the econometric strategy to estimate (1). This consists of implementing three alternative methods: pooled-OLS, within-group (WG) and system GMM. We do so by choosing alternative specifications for the three sets of variables we use: energy, technology and policy variables. Finally, we discuss the main findings.

4.1 Econometric issues

Each specification of equation (1), M1, M2 and M3, is firstly estimated through robust pooled-OLS including controls for both regional and time dummies (Table 2a). Next, we estimate them through WG estimates (Table 2b). With respect to pooled-OLS, the WG has the advantage of dealing with the existence of country-specific (and time-invariant) effects possibly correlated with regressors. However, several authors such as Banerjee and Duflo (2003), Barro (2000) or Partridge (2005), raise some caveats as regards to the WG approach. This is because it may produce inaccurate results for controls that mostly vary in the cross-section, such as growth and energy usage in our case, as the method basically takes into account within-state variability.

Additionally, in dynamic models, pooled-OLS and WG estimates might be affected by an endogeneity bias, at least due to the lagged GDP term included in (1) as a regressor. To address this problem in the absence of suitable external instruments (a standard limitation of growth models), a GMM based approach is a natural alternative in a dynamic context (Arellano and Bond, 1991; Arellano and Bover, 1995). The basic idea is to first-differentiate equation (1), and then employ the levels of the explanatory variables - lagged two or more periods - as internal instruments (i.e., $\ln(\mathrm{Y}_{\mathrm{i,t-s}}), XE_{i,t-s}, X_{i,t-s}$, for *s≥2*), resulting in a first-difference GMM estimator (Arellano and Bond, 1991).

However, using the model only in the first-differences form may lead to important finite sample bias when variables are highly persistent (Blundell and Bond, 1998), which is the case of variables like per capita GDP or energy intensity. An alternative to the first-difference GMM estimator is the system-GMM approach (Bover, 1995; Blundell and Bond, 1998). This consists of estimating a system of equations in both first-differences and levels, where now the instruments of the level equations are suitable lags of the first differences variables (i.e., $\Delta\ln(\mathrm{Y}_{\mathrm{I,t-1}})$, $\Delta XE_{i,t-1}$, and $\Delta X_{i,t-1}$.[7] We consider robust standard errors with a variance-covariance matrix corrected by small sample properties (Windmeiner, 2005; Roodman, 2009). The results for the system GMM strategy are reported in Table 2c.

The validity of the GMM instruments is tested using an over identifying Hansen J-test (Table 2c). It is worth mentioning, though, that the proliferation of instruments (a common issue in system-GMM estimation) tends to produce over identifying problems, and this may call for an instrument's reduction (Roodman, 2009). Under this situation, the p-value of the Hansen J-test tends to be close to one. Bearing this in mind, in our baseline system GMM specification, we limit the number of instruments in the instruments matrix to one. However, when all energy variables are included in the model (third column from each panel in Table 2c), this strategy still leads to a problem of too-many instruments, i.e., the number of instruments exceeds the number of cross-sections and the p-values of the Hansen test hover around one. In this

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[7] Huang et al. (2008) and Marrero (2010), among many others, have emphasized the relevance of using system GMM when working with dynamic panel data growth models. Recently, see Atems and Hotaling (2018) for a similar exercise using the GMM approach.

case, we also show the results when collapsing the matrix of instruments, which further reduces the number of instruments (fourth column from each panel in Table 2c).

Noticing these situations, the Hansen's J-test suggests that the null hypothesis of joint validity of all instruments cannot be rejected in most cases. Moreover, we also compute a difference-in-Hansen tests, which compares the efficiency of system GMM over first-difference GMM in each model (their p-values are always greater than 0.10, see Table 2c).

As a final caveat, it should be mentioned that system-GMM performs better when the number of cross-sectional observations (*N*) is large (i.e., consistency is obtained as *N* tends to infinite). When *N* is not very large and data exhibit a high degree of persistence (which may lead to problems of weak instruments even in system GMM), as in our case, the system GMM estimators can also behave poorly (Binder et al., 2005; Bun and Sarafidis, 2015). Thus, under this situation, as in many macroeconomic applications, it is not evident that a GMM based approach is preferred over robust pooled-OLS (with regional and time dummies) or vice versa. In this situation, it is good practice to report both estimation results (as we do), and verify robustness.

4.2. Main findings

We next show estimation results of models M1, M2 and M3 using robust pooled-OLS (Table 2a), within-group estimates (Table 2b) and system GMM (Table 2c). Table 3 also estimates M1 through M3 using system-GMM, where the share of renewables has been split between "conventional" and "frontier", as defined earlier. Below we describe the main findings.

The role of energy intensity

We provide strong evidence of a robust negative correlation between energy intensity and economic growth at the worldwide level. The coefficients of energy intensity are always negative and highly significant, consistent with Figure 1, which means that reductions in energy intensity are linked to higher GDP growth. This qualitative result is also robust to a change in the econometric method used. For pooled-OLS in Table 2a, we find that, on average, a one percent reduction in energy intensity is associated with an increase in the per capita growth rate of between 0.6% and 0.7%, depending on the model used. This elasticity estimates a range between 0.54% and 0.64% for the WG approach, and between 0.63% and 0.94% for system GMM. Indeed, the main differences in point estimates are due to the econometric method used rather than to the effect of the alternative controls included in model (1). Thus, the observed correlation between energy intensity and economic growth at the worldwide level seems to be driven either by a direct effect, or by indirect channels not observed or not considered in the model such as the quality of institutions, more than through the controls included in the model.

Existing literature has long discussed the negative relation between energy intensity and economic growth for developed countries. Our findings confirm such a negative relation not only for developed countries but also at the worldwide level. The rationale of the negative correlation is that common patterns of structural change, paired with rising after-tax energy prices, bring about an efficient use of energy along the balanced growth path, that is, at given rates of technological progress.[8] This economic transition from 1960 has occurred in a scenario of moderate (before tax) market prices for energy, out of the oil shocks of the seventies and past decade. In particular, note that low energy taxation is consistent with small government size. At the same time, the existing macroeconomic literature (cf. Atkenson and Kehoe, 1999; Díaz and Puch, 2004, 2016) has assumed a production technology that features imperfect substitution between capital and energy. Consequently, our evidence at the worldwide level may suggest that capital deepening at given rates of technological progress brings about an efficient use of energy along the transition to the balanced growth path.

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[8] Filipovic et al. (2015) scrutinize which are the determinants of energy intensity in 28 EU member countries. They find that energy prices (mainly), energy taxes and GDP per capita are likely behind the degree of energy intensity. This result is corroborated by experiences in Denmark, Germany and Italy.

The role of primary energy mix

The second relevant result regards the relationship between growth and changes in the primary energy mix towards renewables (θ_1^m in expression (2)). In Tables 2a-2c, we consider renewable technologies as a homogenous block, while in Table 3 we distinguish between two types, the aforementioned conventional (hydro and biomass) versus frontier renewables (wind, solar, geothermic or wave). When renewables are taken as a whole (Tables 2a-2c), or when separately considering conventional renewables (Table 3), the associated coefficient is always negative and significant, going from -0.42 to -2.2. This indicates that the switch from fossil fuels to renewables (neglecting the type of renewable), albeit environmentally friendly, is not a free lunch, as it can be harmful for GDP growth.

However, according to the results in Table 3, if the move is oriented towards “frontier” renewables, the association with economic growth is positive although weakly significant, with the estimated between 0.5 and 0.6. In other words, this switch from fossil fuels to “frontier” renewables (all other shares, energy intensity, and the state of technology given) might help reconcile CO2 emission curbing policies with economic growth. Therefore, while moving resources from dirty to clean- energy technologies generally produces adjustment costs that may erode growth capacity, it turns out that the quality of the move matters. Our estimates in Table 3 suggest that the sign of the correlation, between renewables and growth rate, changes when we move to “frontier” rather than “conventional” renewable sources.[9]

It is also worth mentioning that when removing energy intensity from expression (1), the change in the renewables’ share is no longer significant to help explain economic growth. This result arises due to a significant relationship between changes in energy intensity and the energy mix (i.e., due to common technological progress or environmental legislation). It also emphasizes the importance of considering

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[9] Inglesi-Lotz (2016), Bhattacharya et al. (2016), Bhattacharya et al. (2017) or Narayan and Doytch (2017), who find a positive impact.

simultaneously these two energy aspects (primary energy mix and energy intensity) to understand growth differences between countries, which is a contribution with respect to other papers in the related literature (Inglesi-Lotz, 2016, Bhattacharya et al., 2016, 2017, or Narayan and Doytch, 2017), as commented in the Introduction.

Finally, moving from fossil fuels to nuclear plants has no effect on GDP per capita growth. In almost all cases, the coefficients θ_2^m in expression (2) are not significant (estimates under fixed-effects for the skeleton model M1 is an exception). Our view, at the worldwide level, rather suggests that a move to nuclear might be unnecessary, unfeasible, or both, for either a small or a low-income country.

Convergence in income per capita

We find evidence of conditional convergence in the pooled-OLS and in the fixed-effects regression, Tables 2.a and 2.b, respectively, indicated by the lagged log-level of income. Convergence appears stronger in the latter case (4.3% on average versus 0.6%), as it is expected from fixed-effects. The reason is that regression under data pooling tends to produce speeds of convergence biased upwards.[10] For system GMM, however, the convergence parameter is not significant in most of the cases.

As an additional exercise, in Table 3, we show that removing the energy intensity variable from the regressions brings extra significance to the conditional convergence hypothesis of per capita income (i.e., notice that removing energy intensity changes makes the lagged income term in (1)) more negative and more significant. Moreover, it also enhances the role of technological variables, even at the expense of policy variables (reported in the last three columns of Table 3). We interpret this finding as an evidence of the key role that the observed downturn in energy intensity plays on income convergence along the transition to sustained growth path. Moreover, it is also evidence of the importance of the energy intensity as a transmission channel.

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[10] This finding was earlier confirmed by papers such as Islam (1995), and Caselli et al. (1996), among others.

In the last three columns of Table 3, the lagged level of income becomes significant in the GMM estimation when we neglect the energy intensity, as well as we differentiate renewables between conventional renewables (hydro or biomass) and "frontier" renewables (wind, solar, wave or geothermic). In such a specification, we always control for changes in the share of nuclear energy. As before, the finding is that changes in the primary energy mix affect growth through changes in the share of renewable energies. However, the result here implies that the transmission channel is particularly evident when we abstract from the role of changes in energy intensity. A rationale for this result is that some countries are possibly constrained in the growth process, either by rising prices of fossil energy or by adopting new energy technologies, or possibly both. As a consequence, they might be switching to inefficient conventional renewables as a response to any obstacles during their decision-making process of the optimal energy technology. If this is so, it is not surprising that once we control for changes in the primary energy mix in those countries, the neoclassical growth mechanisms show up, and conditional convergence cannot be rejected.

Sectoral composition

Finally, the inclusion of sectoral variables (final consumption of energy in sector s relative to total final consumption, i.e. $\Delta s_{k,i,t}$ in (2)) has little effect over GDP per capita growth worldwide. The only remarkable exception is the share of energy demanded by the residential sector. The estimated contribution to growth of this variable ranges within the interval -0.23 to -0.11, depending on the specification and method. On average, for one percent deviation in the residential sector energy share, relative to the share of agriculture, it can be associated with a change of -0.16% in GDP per capita growth rate. This is worth highlighting, given the secular downward trend in agriculture, almost certainly caused by structural change and huge migration from rural areas to the cities in emerging countries, which brings about the upward trend in the residential share of energy along the development path towards steady growth.

[INSERT TABLES 2a TO 2c and TABLE 3 ABOUT HERE]

5.- Concluding remarks

The relationship between economic growth and energy is intricate, as it involves aspects related to institutions and policy, the state of technology, and the sectoral composition of an economy. This paper contributes to this question in that it suggests a specification to measure all these aspects. Our specification incorporates, in a dynamic panel data specification, an indicator of energy intensity, the shares in the primary energy-mix (where we distinguish between renewable sources and fossil fuels), and the sectoral shares where energy is finally consumed. As we use a data set that includes a sample of 134 countries over the period 1960-2010, we also need to control for country specific features. This heterogeneity enriches our analysis, contrary to existing studies that restrict themselves to a reduced set of countries, and allows us to gauge the influence of institutions and policy together with the level of economic development.

Our results confirm a negative correlation between energy intensity and growth at the worldwide level: the higher the energy intensity, the lower the GDP per capita growth. Depending on the model specification and the econometric method, we find, on average, an elasticity of GDP p.c. growth with respect to energy intensity ranging between -0.5 and -1.0 percent. Existing literature has widely reported evidence about this negative correlation for developed countries. We find that this correlation also holds for emerging and developing countries. Moreover, by excluding energy intensity from the regressions we find significant evidence of conditional convergence, and of the role of technological variables even at the expense of policy variables. These findings suggest that improvements in the energy technology are a developmental force.

We further report evidence that those countries that switch from fossil to conventional renewables rather than to frontier renewables, might be experiencing difficulties in their path of development (the coefficients of renewable mix changes are always negative and significant). Therefore, when the situation experienced by a country is controlled for, conditional convergence cannot be rejected.

Finally, only the share of energy demanded by the residential sector matters for GDP p.c. growth. We find values for the elasticity of the GDP p.c. growth with respect to the residential share ranging within the interval -0.23 to -0.11. As the GDP p.c. level widens, households need produce a natural increase in this share which in turn tend to reduce long- term growth. The inclusion of the rest of the sectoral variables is negligible over GDP per capita growth worldwide.

We contribute to the existing literature in that we have scrutinized certain relations between energy intensity, energy mix, sectoral composition and economic growth. Although our results appear fairly robust to alternative estimations, the inclusion of control variables has not been guided under the lens of a formal model. Some other questions affecting the energy-growth relationship, such as the optimal composition of energy sources, requires a dynamic general equilibrium model. The empirical evidence found in this paper will help us to discipline the construction of such a model that will relates alternative energy technologies with technological progress and posterior growth.

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Table 1: Descriptive statistics

		All countries		Low-income		Mid-low income		Mid-high income		High-income (OECD)		High-income (non-OECD)	
Variable	**Unit**	**Mean**	**Std.**	**Mean**	**Std.**	**Mean**	**Std.**	**Mean**	**Std.**	**Mean**	**Std.**	**Mean**	**Std.**
Real GDP per capita	Level, US-2005$/(person x 1000)	14,9	17,8	1,5	0,8	3,4	1,9	8,6	4,0	25,1	11,8	36,6	34,2
Real GDP per capita	Growth rate (%)	2,27	5,44	-0,10	5,55	1,93	7,15	2,83	5,20	2,83	2,33	2,13	7,38
Energy Intensity	TOE (primary) per 1M US$	202,1	143,1	316,1	200,8	227,6	181,6	171,5	100,2	175,1	77,7	201,8	167,9
Fossil share	% w.r.t. primary energy	70,1	28,5	20,6	17,9	51,7	28,4	77,4	17,2	80,9	17,2	97,5	5,9
Renewable share	% w.r.t. primary energy	27,3	29,5	79,3	17,6	49,7	34,3	21,0	17,6	12,3	15,4	1,2	3,9
Nuclear share	% w.r.t. primary energy	2,6	6,8	0,0	0,0	0,8	3,9	1,2	4,8	6,4	9,8	0,9	3,7
Agriculture share	% w.r.t. final energy	2,6	3,2	2,7	4,8	2,0	2,5	3,2	3,3	3,2	3,2	0,5	1,0
Industry share	% w.r.t. final energy	26,2	12,6	11,2	8,4	20,0	10,3	30,2	11,5	30,9	9,3	28,7	15,1
Transport share	% w.r.t. final energy	23,3	11,3	8,3	6,9	19,9	9,2	27,3	10,6	24,3	8,3	30,4	13,0
Residential share	% w.r.t. final energy	32,5	21,2	68,8	21,6	47,7	18,8	26,7	11,7	22,8	8,0	12,0	7,6
Services share	% w.r.t. final energy	6,2	5,7	2,6	3,6	5,2	6,6	4,8	3,5	9,1	4,8	7,1	7,8
Other sectors share	% w.r.t. final energy	9,2	10,5	6,4	12,6	5,1	6,2	7,7	7,5	9,8	6,9	21,3	18,1
	Sample size	915		90		194		253		276		102	

Notes. Source of data, list of countries, period considered, etc.
The shares for fossil fuels, renewable plants and nuclear plants energy have been calculated as the ratio corresponding to the consumption of primary energy relative to total primary energy. The sector shares have been calculated as final consumption of energy in sector s relative to total final consumption.

Table 2.a: Pooled-OLS estimation

Dependent variable: GDP per capita growth (5-year average)

	M1: Skeleton Model			**M2: Model with human capital & investment prices**			**M3: Model with policy variables**		
log(income), lagged	-0.00321	-0.00204	-0.00209	-0.00445***	-0.00368**	-0.00351**	-0.00815***	-0.00677***	-0.00623***
	(-1.65)	(-1.09)	(-1.13)	(-2.60)	(-2.20)	(-2.15)	(-3.88)	(-3.44)	(-3.20)
Energy Intensity, % change	-0.633***	-0.643***	-0.636***	-0.584***	-0.587***	-0.585***	-0.669***	-0.672***	-0.675***
	(-6.82)	(-7.24)	(-7.12)	(-4.99)	(-5.11)	(-5.05)	(-15.96)	(-16.65)	(-16.78)
Renew. Mix, % change		-1.178***	-0.814***		-0.641***	-0.417***		-0.653***	-0.493***
		(-4.26)	(-3.28)		(-3.50)	(-2.69)		(-3.45)	(-2.88)
Nuclear. Mix, % change		-0.0348	-0.00323		0.0720	0.0822		-0.00767	-0.0435
		(-0.15)	(-0.01)		(0.46)	(0.46)		(-0.04)	(-0.23)
Industrial Sector, % change			0.100			0.0306			0.189
			(0.64)			(0.22)			(1.24)
Transport Sector, % change			-0.0457			-0.0395			-0.111
			(-0.22)			(-0.24)			(-0.62)
Residential Sector, % change			-1.105***			-0.863***			-0.688***
			(-5.78)			(-5.37)			(-4.90)
Service Sector, % change			-0.364			-0.177			-0.280
			(-1.01)			(-0.67)			(-1.13)
log(Invest. Price), lagged				-0.00490***	-0.00436***	-0.00316***			
				(-4.70)	(-4.14)	(-3.20)			
Attained primary ed., % over Pop., lagged				0.0247*	0.0263**	0.0248*			
				(1.84)	(2.02)	(1.94)			
Attained secondary ed., % over Pop., lagged				0.00397	0.00893	0.0117			
				(0.34)	(0.76)	(1.01)			
Fertility rate, lagged							-0.00547***	-0.00504***	-0.00510***
							(-3.35)	(-3.24)	(-3.19)
Inflation, 5-year average							-0.00953**	-0.00836*	-0.00572
							(-1.98)	(-1.81)	(-1.35)
Gov. Size, 5-year average							-0.00570**	-0.00530**	-0.00363*
							(-2.51)	(-2.39)	(-1.70)
Openness trade, 5-years							0.00252	0.00243	0.00264
							(0.98)	(1.03)	(1.20)
Num. Obs	915	915	915	814	814	814	744	744	744
R2-adj	0.530	0.578	0.618	0.538	0.558	0.588	0.610	0.633	0.660
Num. Countries	134	134	134	120	120	120	128	128	128

Notes: Regressions above are pooled-OLS results, with constant, regional and time dummies, and robust variance-covariance. Fossil fuel mix is omitted for the primary energy mix (i.e. fossil fuel mix plus renewable mix plus nuclear plants mix amount to one). Agriculture, Cattle and Fishing sector is omitted from the final energy mix (i.e. the final mix for agriculture together with industrial, transport sector, services and residential sector must sum up to one). Figures into parenthesis represent t-statistics. Starred values denote significance at * p<0.10, ** p<0.05, *** p<0.01.

Table 2.b: Within-group estimation

Dependent variable: GDP per capita growth (5-year average)

	M1: Skeleton Model			**M2: Model with human capital & investment prices**			**M3: Model with policy variables**		
log(income), lagged	-0.0500***	-0.0452***	-0.0428***	-0.0448***	-0.0423***	-0.0406***	-0.0417***	-0.0387***	-0.0369***
	(-5.05)	(-4.99)	(-4.86)	(-4.84)	(-4.65)	(-4.47)	(-5.95)	(-5.79)	(-5.64)
Energy Intensity, % change	-0.539***	-0.558***	-0.549***	-0.516***	-0.522***	-0.518***	-0.639***	-0.644***	-0.642***
	(-5.21)	(-5.74)	(-5.62)	(-4.32)	(-4.46)	(-4.35)	(-12.15)	(-13.03)	(-13.20)
Renew. Mix, % change		-1.035***	-0.676**		-0.565***	-0.324**		-0.561***	-0.394**
		(-3.48)	(-2.55)		(-3.24)	(-2.25)		(-3.02)	(-2.37)
Nuclear. Mix, % change		-0.333**	-0.340*		-0.0797	-0.154		0.0134	-0.0904
		(-2.11)	(-1.76)		(-0.44)	(-0.67)		(0.07)	(-0.39)
Industrial Sector, % change			0.148			0.0530			0.195
			(0.98)			(0.43)			(1.37)
Transport Sector, % change			0.213			0.231			0.0765
			(1.00)			(1.30)			(0.48)
Residential Sector, % change			-0.902***			-0.684***			-0.554***
			(-4.73)			(-4.84)			(-3.65)
Service Sector, % change			-0.392*			-0.368			-0.282
			(-1.69)			(-1.42)			(-1.11)
log(Invest. Price), lagged				-0.00466***	-0.00427***	-0.00326***			
				(-4.65)	(-3.84)	(-2.71)			
Attained primary ed., % over Pop., lagged				-0.0141	-0.0106	-0.00733			
				(-0.63)	(-0.51)	(-0.34)			
Attained secondary ed., % over Pop., lagged				0.00848	0.0124	0.0100			
				(0.32)	(0.47)	(0.39)			
Fertility rate, lagged							-0.00578**	-0.00553**	-0.00546**
							(-2.55)	(-2.57)	(-2.58)
Inflation, 5-year average							-0.0102*	-0.00883*	-0.00692
							(-1.87)	(-1.71)	(-1.30)
Gov. Size, 5-year average							-0.0252***	-0.0232***	-0.0211***
							(-3.03)	(-2.83)	(-2.69)
Openness trade, 5-years							0.00865	0.00940	0.00960
							(1.30)	(1.37)	(1.34)
Num. Obs	915	915	915	814	814	814	744	744	744
R2-adj	0.618	0.652	0.680	0.592	0.606	0.628	0.671	0.688	0.706
Num. Countries	134	134	134	120	120	120	128	128	128

Notes: Regressions above are fixed effects estimation results (WG estimates), with time dummies and robust variance-covariance. Fossil fuel mix is omitted for the primary energy mix (i.e. fossil fuel mix plus renewable mix plus nuclear plants mix amount to one). Agriculture, Cattle and Fishing sector is omitted from the final energy mix (i.e. the final mix for agriculture together with industrial, transport sector, services and residential sector must sum up to one). Figures into parenthesis represent t-statistics. Starred values denote significance at * p<0.10, ** p<0.05, *** p<0.01.

Table 2.c: GMM estimation

Dependent variable: GDP per capita growth (5-year average)	M1: Skeleton Model				M2: Model with human capital & investment prices				M3: Model with policy variables			
log(income), lagged	-0.0108	-0.0148	-0.00221	-0.0136	-0.00130	-0.000410	0.000242	0.00709	-0.00921*	-0.00662	-0.00489	-0.00345
	(-0.84)	(-1.51)	(-0.49)	(-0.04)	(-0.26)	(-0.11)	(0.08)	(1.08)	(-1.90)	(-1.59)	(-1.32)	(-0.64)
Energy Intensity, % change	-0.945***	-0.978***	-0.802***	-0.844	-0.687***	-0.663***	-0.629***	-0.701***	-0.871***	-0.778***	-0.734***	-0.821***
	(-11.90)	(-13.30)	(-13.03)	(-0.51)	(-4.68)	(-5.20)	(-5.82)	(-6.65)	(-11.61)	(-10.44)	(-11.69)	(-11.27)
Renew. Mix, % change		-2.171***	-1.126***	-1.377		-0.723**	-0.640**	-1.076***		-0.882***	-0.422*	-1.007**
		(-2.63)	(-2.61)	(-0.28)		(-2.38)	(-2.12)	(-2.80)		(-2.80)	(-1.80)	(-2.55)
Nuclear. Mix, % change		0.194	0.143	-0.275		0.0164	0.0531	-0.249		0.0136	-0.252	0.142
		(0.83)	(0.52)	(-0.04)		(0.11)	(0.15)	(-0.84)		(0.06)	(-0.64)	(0.48)
Industrial Sector, % change			-0.0451	-0.242			0.248	0.278			0.0524	0.00182
			(-0.12)	(-0.04)			(0.89)	(0.84)			(0.21)	(0.01)
Transport Sector, % change			-0.172	-0.322			0.104	0.128			-0.220	-0.428
			(-0.55)	(-0.11)			(0.45)	(0.72)			(-0.92)	(-1.31)
Residential Sector, % change			-1.188***	-0.789			-0.793***	-0.533*			-1.009***	-0.668***
			(-3.71)	(-0.23)			(-3.97)	(-1.76)			(-3.59)	(-2.60)
Service Sector, % change			-0.286	-0.736			0.0355	-0.133			-0.402	-0.412
			(-0.77)	(-0.09)			(0.07)	(-0.40)			(-1.05)	(-1.23)
log(Invest. Price), lagged					-0.00361***	-0.00335***	-0.00250***	-0.00240***				
					(-3.03)	(-3.11)	(-2.71)	(-3.20)				
Attained primary ed., % over Pop., lagged					0.0100	0.0106	0.0157	0.0379				
					(0.22)	(0.32)	(0.53)	(1.23)				
Attained secondary ed., % over Pop., lagged					-0.0458	-0.0371	-0.0137	0.0147				
					(-0.99)	(-1.11)	(-0.55)	(0.18)				
Fertility rate, lagged									-0.0106***	-0.00846***	-0.00650**	-0.00656*
									(-2.68)	(-2.97)	(-2.41)	(-1.74)
Inflation, 5-year average									-0.000238	-0.000426	-0.000454	-0.000734***
									(-0.98)	(-1.32)	(-1.36)	(-2.97)
Gov. Size, 5-year average									-0.0176**	-0.0181***	-0.0132**	-0.0290**
									(-2.32)	(-3.13)	(-2.25)	(-2.32)
Openness trade, 5-years									-0.00276	0.00437	0.00110	0.0148
									(-0.27)	(0.60)	(0.15)	(1.01)
Num. Observations	915	915	915	915	814	814	814	814	744	744	744	744
Hansen test (p-val)	0,003	0,084	0.773	0,069	0,036	0.413	1.000	0.360	0,084	0.455	1.000	0.179
Hansen-diff-test (p-val)	0.021	0.419	0.998	0.234	0.693	0.984	1,000	0.777	0.469	0.970	1,000	0.461
m1-test (p-val)	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
m2-test (p-val)	0.873	0.633	0.906	0.790	0.643	0.709	0.605	0.969	0.490	0.792	0.284	0.837
Number of countries	134	134	134	134	120	120	120	120	128	128	128	128
Number of Instruments	44	78	148	87	98	132	202	117	109	142	209	125

Notes: Regressions above are system GMM results, 2-step, robust, including one lag in the matrix for instruments. Fossil fuel mix is omitted for the primary energy mix (i.e. fossil fuel mix plus renewable mix plus nuclear plants mix amount to one). Agriculture, Cattle and Fishing sector is omitted from the final energy mix (i.e. the final mix for agriculture together with industrial, transport sector, services and residential sector must sum up to one). Figures into parenthesis represent t-statistics. Starred values denote significance at * p<0.10, ** p<0.05, *** p<0.01.

Table 3: Growth and the role of Energy Intensity: System GMM estimates

Dependent variable: GDP per capita growth (5-year average)	**M1**	**M2**	**M3**	**M1**	**M2**	**M3**
log(income), lagged	-0,00842	-0,00624	-0.0121***	-0.0477***	-0.0305***	-0,011
	(-1.40)	(-1.32)	(-3.33)	(-4.53)	(-4.15)	(-1.36)
Energy Intensity, % change	-0.675***	-0.650***	-0.745***			
	(-6.48)	(-5.17)	(-12.58)			
Renew. Mix, % change				-0,344	-0,145	-0,824
				(-0.89)	(-0.47)	(-1.60)
Renew. Mix (Conventional), % change	-1.209***	-0.540*	-0.687**			
	(-2.88)	(-1.80)	(-2.45)			
Renew. Mix (Frontier), % change	0.587*	0.598*	0,388			
	(1,74)	(1,77)	(0,76)			
Nuclear. Mix, % change	-0,217	-0,36	-0.554*	-0,424	-0.860**	-0.773*
	(-0.48)	(-1.05)	(-1.68)	(-0.74)	(-2.08)	(-1.68)
Industrial Sector, % change	0,0871	0,16	0,14	0,339	0,386	0,0007
	(0,42)	(0,87)	(0,89)	(1,07)	(1,54)	(0,0)
Transport Sector, % change	0,162	0,165	0,0439	0,483	0,536	0,687
	(0,69)	(1,0)	(0,25)	(1,15)	(1,45)	(1,46)
Residential Sector, % change	-1.217***	-0.915***	-0.677***	-1.489***	-0.959***	-0.903**
	(-4.28)	(-3.89)	(-3.68)	(-4.27)	(-2.88)	(-2.08)
Service Sector, % change	-0,396	-0,0718	-0.559**	-0,546	0,0862	-0,465
	(-1.25)	(-0.21)	(-2.17)	(-1.17)	-0,22	(-1.16)
log(Invest. Price), lagged		-0.00309**			-0.00741***	
		(-2.09)			(-3.88)	
Attained primary ed., % over Pop.,		0.0711***			0.182***	
		(3,03)			(4,63)	
Attained secondary ed., % over Pop.,		0,000387			0.0873**	
		(0,02)			(2,24)	
Fertility rate, lagged			-0.0158***			-0.0132**
			(-3.93)			(-2.19)
Inflation, 5-year average			-0.000453*			-0,000334
			(-1.74)			(-0.56)
Gov. Size, 5-year average			-0.0183**			-0.0335*
			(-2.12)			(-1.66)
Openness trade, 5-years average			0,00309			-0,0044
			(0,42)			(-0.27)
Num. Observations	915	814	744	915	814	744
Hansen test (p-val)	0,0205	0,506	0,845	0,00873	0,148	0,146
m2-test (p-val)	0,862	0,718	0,682	0,943	0,398	0,0172
Number of countries	134	120	128	134	120	128
Number of Instruments	110	142	151	91	123	121

Notes: Regressions above are system GMM results, 2-step, robust, including one lag in the matrix for instruments. Fossil fuel mix is omitted for the primary energy mix (i.e. fossil fuel mix plus renewable mix plus nuclear plants mix amount to one). Agriculture, Cattle and Fishing sector is omitted from the final energy mix (i.e. the final mix for agriculture together with industrial, transport sector, services and residential sector must sum up to one). Figures into parenthesis represent t-statistics. Starred values denote significance at * p<0.10, ** p<0.05, *** p<0.01.

Figure 1: Facts on income, energy intensity, and renewable sources.