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Energy patterns for developing countries- an energy intensity decomposition analysis for economies in Asia and in Latin America

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Abstract: Motivated by the increasing importance of today's environmental issues as well as by the increasing concerns related to energy use, the study is intended to perform an energy intensity decomposition in order to analyze the effects of structural and technical changes on the energy patterns and in specific on the energy intensity of ten major developing countries in Asia and in Latin America. The main focus is placed on the changes that describe the service and industrial sector in these countries and their effects on energy intensity while the results provide some insight concerning the role of these countries in today's global production system.
Changes in the service sector are not significant drivers of the decline in energy intensity for all the countries examined. On the contrary, technological changes in industry and transportation are the main determinants for the decline in total energy intensity for four of the developing countries. For the rest, the strong industrialization process tends to increase energy intensity, a trend that is outweighed by the contribution of the residential sector.

Key words: Economic growth, energy, energy intensity, decomposition analysis

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1 Introduction

Environmental issues gain continuously more popularity and seem to have a central role in all political discussions that aim at the establishment of global “sustainable” developmental strategies. Under the threat of global warming and the gradual depletion of natural resources, the underlying mechanisms that characterize the interplay between economic activity and the environment come at the centre of the analysis. These mechanisms have historically been the main determinants of environmental degradation as they imply specific processes of resource and energy management. In particular, since the first Industrial Revolution, our world has experienced a tremendous growth in both aspects, economic and social, that also triggered continuous changes on the patterns that characterized energy consumption and energy use. During the last two hundred years, per capita energy consumption has been continuously increasing, and thus energy consumption is quite improbable to decline in the near future (UNIDO, 2011). According to Kander et al. (2012), during this period and specifically from 1820 until 2000, the average annual growth rate of energy consumption per capita, in Western Europe, has been around 1.10%.

In this two century period, as stated by Kander et al. (2012), distinct development blocks have emerged, with different energy carriers (coal, oil, electricity) and around radical innovations, that determined the patterns of energy use. However, the potentials for economic growth, partly hindered by the growing demand for energy services, have increased in significance mostly after the oil price shocks that occurred during the 1970s and in particular in 1973 and 1979 (Nilsson, 1993). As stated by MacKillop (1990), the relationship that characterize energy and growth in OECD countries, can be distinguished in two different periods, before and after 1973. The period before was characterized by a coupled relationship between energy and economic growth (meaning that the GDP elasticity of energy was equal to one or more) while during the 1970s a gradually increasing decoupling process starts to emerge (MacKillop, 1990). This process, which is noticed in the second time period, coincides with the beginning of the third Industrial Revolution or Information and Communication Technologies (ICT). In detail, this revolution, enforced by the further integration of electricity, enabled the emergence of new relatively more “energy saving” innovations (such as the microprocessor and the transistor) that favored structural and technical changes mainly in developed countries (Kander et al. 2012). Electricity, being a more flexible source of energy that can be easily used by a wider range of technologies, led to energy efficiency improvements and increases in productivity for many developed economies, while triggering structural shifts towards less energy intensive industries and a modest transition to services (Henriques and Kander, 2010, Nilsson, 1993).

However, as stated above, until today it is mainly developed economies that have taken an active role in this new era while the vast majority of the developing countries are still in a transition process of fully adopting the merits from the third Industrial Revolution related with energy savings. The challenges that developing countries are facing and along with them the whole world, given that pollution knows no boundaries, are based on the interplay between the rising living standards and the dangerous environmental effects that are implied by higher levels of energy consumption in these economies.

As these economies increase their income per capita and narrow the gap with developed countries, per capita energy consumption is expected to increase as they enter into a new phase of industrialization (UNIDO, 2011). Their growth raises many questions concerning the production structures of these economies and brings at the center of the analysis the role of industry and services. More specifically, changes in the shares of these sectors imply radical changes in the already established patterns of energy use and raises concerns about the potential of these economies to overcome the challenge. Their main obstacle is found in the lack of adequate infrastructures and capital markets that would allow them to develop energy efficient technologies and consequently decrease their ecological footprint (Arrow et al. 1995). At the same time, the increasing role of the service sector in developed countries raises questions of whether this is a generalized phenomenon that also takes places in developing countries and in that way could affect energy intensity (Henriques and Kander, 2010). Finally, all the abovementioned become even more important if we account for population increases, as these countries exhibit substantially greater growth rates than developed economies. This fact implies greater increases of energy consumption and makes concerns related with resource depletion and environmental degradation even more severe (UNIDO, 2011).

1.1 Research focus and research question

This thesis contributes to the discussion around the effects of economic growth for developing countries' energy intensity. The historical changes in the development patterns, production structures and energy consumption of ten major developing economies in Asia and in Latin America are examined while at the same time the capacity of these economies to absorb the benefits from the third industrial revolution is analyzed and is reflected in the decomposed patterns of energy intensity. In detail, in the current study an energy decomposition is performed in order to analyze the effects of structural and technical changes on the energy patterns and specifically on the energy intensities of India, Indonesia, Philippines, Thailand, South Korea, Brazil, Mexico, Colombia, Argentina and Peru. The main focus will be placed on the changes that describe the service and industrial sector in these countries and their effects on energy intensity while the results will provide some insight concerning the role of these countries in today's global production system. Consequently, the main question to be answered in the thesis is formulated as follows:

How do structural shifts and especially changes in the service and industrial sector affect energy intensity in developing countries?

The first section of this study provides a broad overview in order to introduce the historically recorded interplay between economic activity and energy and establishes the problem for developing countries. The second section presents the theoretical framework as well as outcomes from previous studies. The main focus is placed on the historically recorded processes of structural change as well as on the factors that can affect energy productivity. In section three, the data used are presented while in section four the Logarithmic Mean Divisia Index (LMDI) method, which is chosen for decomposing energy intensity in within-sector and between-sector changes, is described. Section five initially reflects on the role of these countries in the global economy, moves on to analyze the structural changes in services and industry, and finishes by presenting a reflection on the results of the decomposition analysis. Finally, in the last section, the main outcomes of the research are summarized while some implications are drawn that broaden the discussion.

2 Theoretical background and hypothesis

Since the third Industrial Revolution there has been under way an enforced trend of globalization and economic integration. Such a trend has gradually been favored by decreases in transportation costs as well as by the radical innovations introduced (by the ICT revolution) which have contributed significantly to the decrease of distance and the easier and faster transferability of information. Such a process is generally assumed to have been accompanied by a transition, mainly referred to as structural change, which has been underway for several decades and that has transformed both the processes as well as the types of production in many developed as well as developing countries affecting in this way the energy consumption and consequently the pollution patterns that characterize these economies (Henriques and Kander, 2010).

There are various indicators that can be used in order to assess the impact of economic activity on the environment. As stated by Kander et al. (2012), energy intensity is a commonly used indicator by economists and historians, which can provide insights on the relationship between energy consumption and economic growth. It is an efficiency measure that stems from the energy consumption/ output ratio and represents the quantity of energy employed for the production of one unit of output (usually measured in terms of value added). As a result, it can be used in order to quantify, in an indirect way, environmental degradation by examining the evolution patterns of developed and developing countries regarding climate change (Ang, 1999). Furthermore, in contrast to other indicators, such as the "carbon factor" (Mielnik and Coldemberg, 1999), energy intensity tends to vary more, both over time and across different countries (Ang, 1999). Being dependent on a greater number of influencing parameters, it proves to be a reliable indicator for analyzing different patterns of energy use as well as their implications for the environment. However, it needs to be noted that energy intensity is not a sufficient indicator on its own, but needs to be complemented by the scale of total energy consumption that characterizes an economy, so that more meaningful results can be drawn in relation to the environment.

Environmental impact is commonly related with pollution (land, air and water) while greenhouse gas emissions (GHG) are assumed to be the major environmental challenge of today (UNIDO, 2011). According to Stern (2004), the level of pollution as well as the exploitation of natural resources in an economy is determined by direct and indirect effects. More specifically, the direct effect on pollution is related to changes in the scale of production, changes that are related with technological innovations that aim at productivity increases and emissions' reduction, as well as with transformations in the structure of an economy ("product mix") or in the resources used. Consequently, the patterns of energy intensity are determined by the relative impact of the scale effect, that in absolute terms tends to increase energy consumption, as well as by structural and technological effects that take place in an economy and potentially can outweigh such increases, leading to environmental improvements for a country (Henriques and Kander, 2010). In addition, the indirect effects refer to environmental regulations, awareness or the degree of openness to the rest of the world (international trade), that characterizes an economy, and consequently can affect in an indirect way its production structure and consequently its energy intensity patterns (Stern, 2004, Kander, 2005).

As developing countries grow, the demand for energy services is continuously rising and as stated by Nilsson (1993), the higher income levels in these countries increase the demand for energy using products such as cars and air conditioners, triggering in that way the expansion of the production structure in these economies (scale effect). Especially for increases at lower incomes, that is the case of developing countries, the demand for basic infrastructures such as road networks and housing imply the use of highly energy intensive inputs such as steel rods, aluminum products and other (Schäfer, 2005). In fact, according to a study done by UNIDO (2011), in 2008 developing economies had almost 30% higher per capita industrial energy consumption than more developed countries. In addition, the more energy intensive regions are considered to be Eastern Europe, sub Saharan Africa, South and Central Asia while economies in Eastern Asia, Latin America and Middle East are rated as less energy intensive (UNIDO,2011). This expansion of production is also reflected in the pollution patterns of developing countries. The study by Olivier and Peters (2010), shows that among the top twenty-five emitting economies in the world, that make up more than 80% of global CO_2 emissions, there are many developing countries, some of which will be examined in the current study. In contrast to more developed economies like Germany, Canada and the UK, the majority of the developing countries demonstrate increases in CO_2 emissions during the last decade while in other cases they just remain constant at high levels (Olivier and Peters, 2010). Furthermore, according to Jung et al. (2000), the prominent role of population growth and urbanization in these countries also implies higher levels of production and energy use, while at the same time such factors tend to be the drivers of structural changes in these economies.

The term structural change mainly refers to between- sector changes that occur in an economy and can affect in different ways the ratio of energy consumption to GDP. For instance, an economy that shifts from a primarily agricultural production towards industry, it is expected to use more energy in relation to the value produced at this new stage of development given that different industries have distinct pollution intensities (Stern, 2004, Kander et al. 2012). Consequently, theory suggests that with structural changes energy intensity increases when the relative size of more energy intensive sectors increases (Nilsson, 1993). For many developed economies it is generally assumed that a “transition to a service economy” can lead to environmental improvements as the sector is in general less energy consuming in relation to its value produced, driving in that way decreases in energy intensity (Kander, 2005).

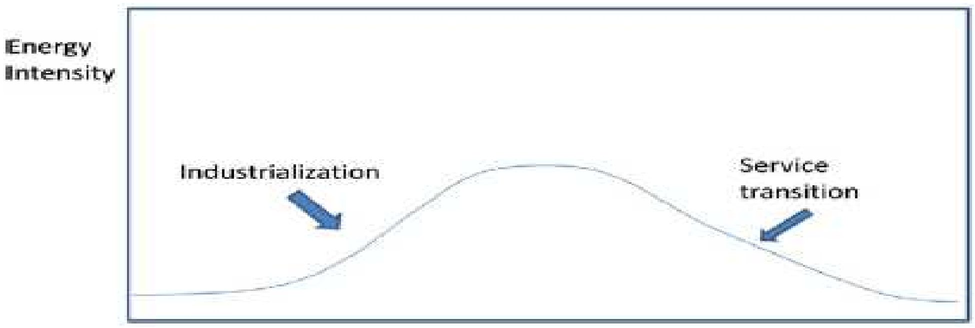
Furthermore, as mentioned before, the last factor that can directly affect energy intensity of an economy is technical change. As stated by Henriques and Kander (2010), it mainly refers to within- sector changes that tend, through the application of new technologies and innovative production processes, to decrease the real energy intensity of a sector. Technical change imply the transformation or upgrading of the already established production techniques, leading to relatively more energy efficient production processes for all the sectors in an economy and especially for industry (Mielnik & Goldemberg, 1999). Furthermore, technical change may also imply shifts to lighter and less energy intensive subsectors, i.e. structural changes at a lower level of disaggregation (Henriques and Kander, 2010).

Finally, in accordance to the indirect effects that as mentioned before can affect energy intensity, at this point it should be noted that the energy patterns of developing countries should also be examined in the light of further economic integration and trade liberalization that has taken place in the last four decades. There is a widespread belief that the developing countries today tend to get the role of being the factory of the world as the manufacturing production is shifting from the developed to less developed economies (Henriques and Kander, 2010). According to Grossman & Krueger (1991), trade can also affect the scale of production and consequently the structural and technical changes that can occur in an economy. In addition, as stated by Copeland & Taylor (1994), greater degree of openness implies that international trade will tend to increase the scale of the economy and given that the production methods in these countries can in some cases be relatively old, this could result in higher energy intensities. However, it could also be argued that import of capital goods may have two different and opposite effects for developing countries (Suri and Chapman, 1998). On one hand they may have a substitution effect that will tend to decrease energy intensity by substituting older and relatively inefficient machinery with new ones. At the same time they may have a complimentary effect as they are used in the production of relatively more energy intensive products for these countries and add up to the already established production techniques increasing the scale of the economy and its energy demand. Although acknowledging that the indirect impact of trade on energy intensity exceeds the analysis of this study, it is argued that by looking in the economic structures of such developing economies it is possible to draw some conclusions concerning its role.

2.1 Previous studies

The abovementioned mechanism of expanding production that at the same time is accompanied by structural and technical changes, affecting the energy intensity patterns of an economy, has graphically been presented by the Environmental Kuznets Curve (EKC). According to Panayotou (1993), and as presented in Figure 1, the EKC is an inverted U-shaped curve which implies that, as a country is going through its process of industrialization, energy intensity is expected to increase up to a maximum while latter on as the service sector will increase its share, the transition of the economy will lead to environmental improvements as energy intensity will decline.

Figure 1. Energy intensity and structural change



Source: Henriques and Kander (2010)

Kander et al. (2012) argue that some personal services like psychotherapy and hairdressing do not consume the same amount of energy as steel- making per unit of income. As a result, an economy that has a relatively larger share of such services will demonstrate lower energy intensities. Additionally, it has been observed that historically, as income increases, environmental degradation also increases up to a point after which environmental quality starts to improve (Arrow et al. 1995).

However, in contrast to the proposition done by the EKC hypothesis, other studies strongly question the importance of the transition to a service economy as the main driving force for decreases in energy intensity. Although the service sector might increase its share in an economy, this increase is relatively modest when the value added of the sector is measured in constant prices. As stated by Kander (2005) in the case of Sweden, the share of the sector in an economy's production may not increase that much when its real value added is measured. Furthermore, Henriques and Kander (2010), in their study for ten major developed and three developing economies, show that the share of the service sector, measured in constant prices, did increase but the increase was significantly smaller for the majority of the sample when compared to that in current prices. This structural change did contribute to a certain degree but was not the main driving force behind changes in energy intensity. In contrast, the key determinants were real intensity changes that stemmed from technological innovations, increasing productivity in these economies, or were the result of within- sector changes in industry, that resulted in shifts to lighter subsectors of production (Henriques and Kander, 2010).

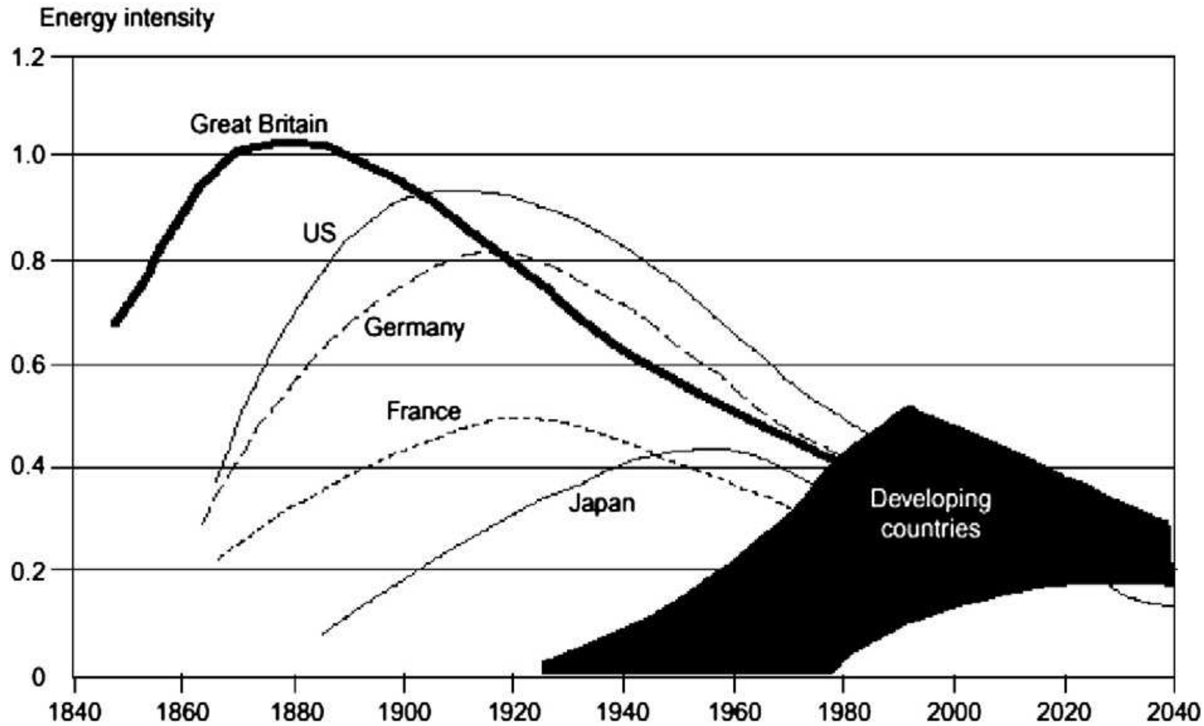
The reason why measurements in current prices does not prove to be a valid method when accounting for changes in energy patterns, is mainly because the actual production of the sector is not in accordance with its value added over time. Such an argument is based on what Baumol (1967) called "cost disease", that is related with increases in the costs of a sector that are not accompanied by relative increases in its productivity. In his model, the main assumption is that economic activities can be divided in two different types. In detail, an economy is comprised by technological progressive activities (such as industry/ manufacturing sector) as well by non-technological progressive (such as part of the service sector). According to the quite influential study, innovations and capital accumulation can occur and lead to increases of productivity (output per man hour worked) only in the industrial/ manufacturing (progressive) sector triggering in that way higher wages. These rising costs expand to other non technological progressive sectors of the economy, such as services, where the substitution of labor by capital is difficult to occur (in some cases labor is the only factor of production) (Baumol, 1967). In that way an imbalance is created between productivity and wages in the non- progressive sectors. Consequently, measurements in current prices for the service sector may provide misleading results concerning the actual contribution of the sector (in real terms) and may not allow for more precise interpretations concerning the determinants of energy intensity patterns.

However, at this point it is also worth mentioning that the technological innovations that have been under way during the last decades do not only affect the productivity of the industrial sector in an economy but as well the service sector and have gradually resulted into what is called today "industrialization of services" where the substitution of labor by capital is possible (Broadberry, 2006). In reality, and as stated by Baumol et al. (1985), the service sector can also contain some of the economy's most progressive activities and consequently the division between stagnant services and progressive industry may not be so absolute. More specifically, such activities are called "asymptotically stagnant" (neither stagnant nor progressive) and may use in certain proportions inputs from both the progressive as well as the stagnant sectors of the economy (Baumol et al. 1985). As stated by Levitt (1976), the supermarket could represent the industrialization of older retail services while the modern assembly lines can be seen as the industrialization of past craftsmanship procedures. Consequently, it can be assumed that for this part of the service sector "cost disease" may not occur as increases in value added can be translated in increases of productivity.

In addition to the U- shaped pattern that has been proposed by the EKC for energy intensity, it has also been noticed that countries with peaked energy intensities later in time tend to peak at lower levels of energy intensity due to the availability of better and more energy efficient technologies. As presented in Figure 2, the stylized graph by Reddy and Goldemberg, cited in Henriques and Kander (2010), shows that as we move forward in time energy intensity for all developed countries in the graph tends to peak at lower levels as they enter later the phase of industrialization and at the same time adopt more efficient production techniques. As stated by Nilsson (1993), the energy intensity peaks of countries like USA, Germany, France, Italy and Japan have been decreasing at a rate of approximately 1.5% per year.

Consequently, and as shown in Figure 2, the main proposition of the stylized EKC hypothesis for developing countries is that they will follow the same U-shaped path, however peaking at relatively lower levels of energy intensity. Benefiting from the knowledge and technologies used in industrialized countries, they will adopt cleaner and more efficient technologies as a result of a leapfrogging process (Henriques and Kander, 2010). In such a way, they can avoid the patterns followed by industrialized countries and converge within a smaller range of energy intensity (Mielnik and Goldemberg, 2000). Cases in point are the economies of Brazil, India and Mexico as reported in Henriques and Kander (2010).

Figure 2. Traditional assumption for the historical evolution of energy intensity



Source: Reddy and Goldemberg (1990) cited in Henriques and Kander (2010)

These three developing countries, when compared to ten more advanced economies, included in the same study, converge at the same relatively low levels of energy intensity. Furthermore, in his study for the period 1975- 1985, Nilsson (1993), finds that countries like Brazil, South Korea, Indonesia and Thailand, start at higher levels of energy intensity when compared to other developing countries like India, Mexico and Argentina, suggesting in this way that the pattern of energy intensity convergence does exist between developing countries as well. In addition, in Reister's (1987) study, of energy intensity for 38 developing countries during the period 1950- 1980, it is found that energy intensity increases as these countries develop while such an increase is driven from the transition of these countries from a rural self- sufficient agricultural economy to a new industrial society. Although, at this point it is worth mentioning that the pattern of convergence in the EKC is highly dependent on the measurements used when accounting for GDP. Particularly, the main problem arises from the differences between measurements of GDP in Purchasing Power Parities (large convergence) and exchange rates (smaller convergence) that as will be analyzed in the following section of the study, can lead to overestimations or underestimations of GDP, affecting energy intensity.

Concluding, having established the general theoretical framework that describes the historically recorded causal relationships between energy and economic growth, it is interesting to investigate in detail the actual energy patterns that describe energy intensity in ten developing countries. Furthermore, it will be able to examine whether a service transition exists for theses economies and also analyze the overall process of industrialization that has been under way during the last 35 years and specifically from 1971- 2005, comparing it to the patterns followed by more developed economies. Furthermore, assuming that the industrialization of services is mainly a process that to a higher degree takes place in the developed countries, it is intriguing to see whether it applies for developing economies especially if we take under consideration the fact that the majority of the manufacturing needed for the industrialization process takes place in these countries. Finally, the research is expected to provide some answers concerning the sustainability patterns that describe the current subcontracting global production system, which is assumed to shifts production from the developed to less developed economies.

2.2 Hypothesis

The previous theoretical background designates that the following hypothesis should be tested:

1. *The developing countries' energy intensities, when presented graphically over time (1940-2005), will follow the same stylized U-shaped pattern proposed by the Environmental Kuznets Curve hypothesis; there will be a steep decline after the 1980s.*

In addition, one must be cautious when examining the impact of the service sector in changes of energy intensity and consequently the following hypotheses emerge as well:

2. *The developing countries will show some transition to the service economy in the sense that services increase their share of GDP as well as of total employment when measured in current prices*

3. *The developing countries will not show any increase of the service sector share of GDP when measured in constant prices (or the increase will be relatively less compared to the one in current prices)*

3 Data

For the longitudinal study secondary interval data will be used that is expected to give an insight of the potential changes that have taken place over the last three decades and specifically from 1971 until 2005. There exist data for five Asian countries and five countries in Latin America and the sampling procedure was mainly based on the availability of data as the lack of adequate information is common for developing countries (especially in respect to energy). In detail, there is available data for the economic sectors as well as their energy consumption for the following countries: India, Indonesia, Philippines, Thailand, South Korea, Brazil, Mexico, Colombia, Argentina and Peru. The relatively big sample size will allow for comparisons between the countries and consequently will provide greater validity concerning the results that will be obtained. It is not the primal intention of the study to provide more in depth information concerning each country separately. The purpose is rather to make a comparative analysis concerning the processes under way, both within the cohort under study (developing countries), as well as between the patterns that characterize more developed economies. In detail, comparisons and correlations in terms of energy trends will be drawn with ten developed economies as well as with Brazil, India and Mexico, which have been reported by Henriques and Kander (2010).

The case study, will allow to test whether the findings that apply in one country are valid for the other countries as well allowing us in that way to draw some conclusions concerning the general pattern that describes the sample. It is however worth mentioning that, as the sampling was based on data availability, this raises concerns and to a certain degree limits the degree of generalization that can be achieved (due to inefficient randomization) for the whole population of developing economies. In fact, the majority of the economies sampled are the relatively more advanced economies in their regions and consequently the results should be analyzed with caution in respect to the overall population of developing economies. Still, it can be assumed that the countries selected are quite representative for higher- middle income developing economies and consequently the results of the analysis will primarily target that group of developing countries.

3.1 *Long- run GDP Data*

In order to provide an overview of the countries' developmental stages over time, and specifically during the last thirty five years, as well as of their energy intensity patterns, GDP values for the sample are acquired from Maddison (2008) database expressed in 1990 Purchasing Power Parities (PPP). The reason why GDP in constant prices is used is based on the fact that, in contrast to energy consumption data, whose value remains the same over time, GDP is measured in monetary terms that can fluctuate over time due to other factors such as inflation. For this reason, when comparing real physical quantities (in this case energy consumption) to GDP, it is necessary to express its value in constant prices (often based on annual linked price deflators) in order to control for variations in its prices (Khatib, 1993). Furthermore, in order to be able to compare energy intensities between countries, GDP needs to be converted to constant dollars by using exchange rates or the Purchasing Power Parity (PPP). In the current study, the PPP method is used since it is considered to be more accurate in expressing the real value of national income. Given that many goods and services are relatively less expensive in developing countries (usually those that are no traded nationally), GDP estimates in dollars based on exchange rates could result in large understatement of GDP for these economies and consequently could overestimate their energy intensities (Nilsson, 1993). If prices and furthermore GDP, are expressed in PPP dollars, disparities in the price levels disappear and more meaningful comparisons can be drawn in terms of energy intensity (Khatib, 1993).

3.2 *Data on economic sectors and final users of energy*

The data concerning the economic sectors of each country were retrieved from the Groningen Growth & Development Center (GGDC) 10- sector database, while the data related with the energy balances in each economy were obtained from the International Energy Association (IEA) database. The databases have been used in several other studies and consequently it can be assumed that the reliability as well as the internal validity of the study can to a reasonable degree be reassured.

Concerning the database relevant to the economic structure of each country, the data were specifically acquired from the database constructed by Timmer and de Vries (2007) for Latin American and Asian countries. It includes a dataset with annual time series of value added in constant as well as current prices and the persons employed, in 10 sectors of the economies, in the period from 1950 until 2005. For some countries data for measurements in current prices are missing. Fortunately, this does not affect the decomposition analysis, since it employs data for each economic sector in constant prices. Value added is calculated in each country's own currency and consequently, no comparisons can be done in terms of the level of energy intensity in absolute terms (this analysis is done with the GDP data from Maddison, 2008). However, this does not prevent country comparisons; on the basis of relative changes in energy intensity which occurred in each economy and were driven by the respective economic sectors.

The level of disaggregation is 10 sectors, and in order to be compatible with the sectoral aggregation in the energy databases, they have been aggregated in 4 main sectors of the economy. Consequently, the 4 aggregated sectors are industry, transportation, agriculture and services. This aggregation was required in order to enable the use of the data in the decomposition method and make them compatible with the data on the relative energy consumption by each sector. Additionally, the disaggregated data for industry and services were also used separately in order to examine in depth how the structures of the ten economies evolved during the period studied. Finally, it is worth noticing, that due to lack of information concerning the sectoral details, Transport and Communication sectors are merged together under the former headline and consequently the energy data may not be in full accordance with the value added of this sector.

Concerning the energy data, the databases reach up until the year 2009, but the data availability of the sectors' value added limits the research to the period until 2005. The data concerning the energy consumption by each of the economic sectors as well as from the residential sector in the countries, as mentioned before, was acquired from the International Energy Agency (IEA) that is probably the most recognized and reliable database concerning energy related numbers for various countries. In particular, the "Energy Balances for non-OECD countries, 2010 edition" database was used for the majority of the countries while the data for Mexico and South Korea were acquired from the "Energy Balances for OECD countries, 2010 edition" database. The databases provides information concerning the supply and demand for all fuels that are used in the countries from 1971 until 2008 and most importantly the statistics on energy production, trade and consumption by each sector are expressed in a common unit, something that makes possible the computation of the energy decomposition. In particular, for the measurement of energy consumption by each sector and the economy as a whole, the common unit of *tones of oil equivalent* (commonly abbreviated as *toe*) was used as it can be easily converted into joules and allow for comparisons between the results from previous studies.

Concerning the level of disaggregation of the fuel uses by sector, as stems from the “Energy Balances” database and due to the fact that the data are collected on a voluntary basis from each country, sectoral disaggregation of consumption is not possible to be done as in some cases data might be missing. It is acknowledged that information on the subsectors of each economy would allow making a more detailed decomposition and would provide more insights concerning the effects of the changes that might have occurred in energy intensity of each sub- sector. As stated by Ang and Choi (1997), a decomposition analysis that is based on highly disaggregated data captures in a better way the effects of changes in the product mix on energy intensity. However, in our study the main focus is placed on the aggregated sectors, i.e. industry, transportation, agriculture, services (commercial and public) and residential sector and data used refer to total final energy consumption by these different end-users.

It is worth noticing that the data on energy consumption by the households exclude fuels used for personal transportation, as they are incorporated in the transport sector. Consequently, the contribution of the residential sector to changes on overall energy intensity change might be partly underestimated. Furthermore, the data on energy consumption account only for the commercial energy that is used while non- commercial energy, such as firewood and animal waste, is not included in the dataset. This could have both positive as well as negative effects for the results. For instance, as stated in Kander et al. (2012), in Agriculture, muscle energy from animals is a key energy source for the sector and consequently its computation would lead to more accurate results. However, the limitations imposed by data availability do not allow the inclusion of non- commercial energy, and as stated by Nilsson (1993), it is better to base energy intensity on commercial energy only, so that there can be achieved a better matching between economic activity and energy consumption. Finally, given that the main focus of analysis is on the energy intensities of developing countries, with great caution it is assumed that the share of non- commercial energy to the total does not demonstrate great variations between the developing countries studied here and so comparisons between them can be drawn.

4 Methodology

The main aim when performing a decomposition analysis in environmental studies is to quantify and consequently measure the impact from changes in various factors on the environmental indicator used (Ang et al. 1998). For the current study, as mentioned before, the environmental indicator used is energy intensity and the factors that affect it are changes in the product mix (between sector changes/ structural changes) as well as changes in the real energy intensity of each sector (within sectors changes/ technical change) (Ang and Choi, 1997). As stated by Ang and Choi (1997), the most commonly used methods in decomposition analysis, are the Laspeyres and the Divisia index methods. However, according to Ang et al (1998), these methods were excessively used in older decomposition analysis while in more recent studies a refined Divisia index method is preferred. The main problem of the older methods is that they both leave an unexplained residual while the Divisia index has problem in accommodating zero values. The revised Divisia index was proposed by Ang and Choi (1997) who modified the formula by incorporating a logarithmic mean weight function, allowing in that way for a perfect decomposition that leaves no residual. Furthermore, it can also accommodate zero values that might exist in the dataset, by giving them very small values, close to zero.

Historically, and according to a study by Liu and Ang (2007) that included 69 information sources (previous environmental studies), it is argued that from the mid 1980s until the mid 1990s, the Laspeyres decomposition method was still the most popular in most studies. However, after 1987, the Divisia index concept was gradually introduced as a new analytical tool, and after 1996 until today the Logarithmic Mean Divisia index (LMDI) (revised Divisia index method) is the most popular method.

Consequently, the method that will be used in order to perform the energy decomposition for all the selected countries, and that will enable to answer the main research question of this study, will be the Logarithmic Mean Divisia Index (LMDI) decomposition that has been proposed by Ang (2005) and as it has been used in Henriques and Kander (2010). The current method will allow measuring the significance of the various changes that have taken place both within as well as between the sectors of these economies and most importantly will provide answers related with their effects on the final energy intensity changes. The method has been used in many energy studies and besides the fact that it is relatively easy to use and interpret the results, probably its best merit, as mentioned above, is that it allows for a perfect decomposition leaving no unexplained residual.

The main variables used in the method are the following:

E	Final energy consumption
E_i	Energy consumption by each sector i
E_k	Energy consumption by the residential sector
Y	Value added
Y_i	Value added by sector i
$I = E/Y$	Total energy intensity
$I_i = E_i / Y_i$	Energy intensity by sector i
$I_k = E_{k/} Y$	Energy intensity of the residential sector
S_i	Share of sector's i value added in the economy
D_{tot}	Change in energy intensity of the economy
D_{str}	Change caused by structural change
D_{int}	Change caused by technical change
D_{pcons}	Change caused by the personal (residential) consumption of energy

The main equations to calculate the changes that occurred during the selected benchmark years 1971, 1990 and 2005 are presented here.

For calculating the change in total energy intensity of each economy the equation (1) is used,

$$D_{tot} = D_{str} D_{\text{int}} D_{pcon} \qquad (1)$$

where the change in energy intensity caused by structural shifts (between- sectors changes) (D_{str}) is given by equation (2).

$$D_{\text{str}} = \exp\left[\sum_i w_i \ln\left(\frac{S_{i,t}}{S_{i,0}}\right)\right] \qquad (2)$$

Technical change (within- sectors change) (D_{int}) that affect total energy intensity are calculated as follows,

$$D_{\text{int}} = \exp\left[\sum_i w_i \ln\left(\frac{I_{i,t}}{I_{i,0}}\right)\right] \qquad (3)$$

while changes that are caused by the energy consumption in the residential sector are given by equation (4).

$$D_{pcon} = \exp\left[\sum_k w_k \ln\left(\frac{I_{k,t}}{I_{k,0}}\right)\right] \qquad (4)$$

Finally, the computation of the weights ($w_{i(k)}$) for all the sectors of the economy, is given by dividing the logarithmic mean of energy intensity of the relevant sector with the total change in energy intensity (equation 6).

$$w_{i(k)} = \frac{L(I_{i(k),t}, I_{i(k),0})}{L(I_t, I_0)} \qquad (6)$$

Where the logarithmic mean function of two positive variables is calculated as follows:

$$L(x, y) = \frac{x - y}{\ln \frac{x}{y}} \qquad (5)$$

5 Data analysis

5.1 Overview analysis

Before moving to the results from the decomposition analysis, it is essential to provide a broad overview of the economies that comprise the sample of the study. It is useful in order to get a basic understanding of the various differences and similarities that exist among the countries under study and their role in the global economy, while at the same time allowing for the testing of the first hypothesis.

Historically, and more precisely since the 1970s, Latin America and East Asia have been the major regions in the world as together they comprised more than half of the global population. Specifically, in 1971 both regions together held approximately 61% of the world's total population, while today their share has increased by almost 3%. The biggest region is East Asia; in 2009 it accounted for almost 3.7 billion people, while Latin American countries make up a significantly smaller share at around 8.6% of the world's total population.

More importantly, the countries that comprise our sample accounted for approximately 2 billion people in 2009 and they make up almost 31% of the world's total population today. They are the biggest countries in their regions and consequently they play a key role in terms of energy consumption both on a regional as well as a global level. In detail, the five Latin American countries examined here account for around 60% of the Latin American population, while the five East Asian countries make up 37% of the whole region.

Concerning their economies, in 1975 the Asian countries under study accounted for almost 6% of the global GDP (measured in constant, 1990 PPP dollars) while in 2005 their share had almost doubled reaching at approximately 11.3% (see Tables A: 1 and A: 2 in the Appendix). In contrast, the Latin American countries didn't experience the same rapid growth during this time period and it could be argued that their role in the global economy, in terms of GDP, somewhat decreased (they made up 6.8% of global output in 1971 and they make 5.8% today). Still, though, some major economies in the region, like Brazil and Mexico, had experienced a period of rapid economic growth. Furthermore, the sampled countries in Latin America, account for the biggest share of the region's economy and in 2005 they made up 75% of the value added.

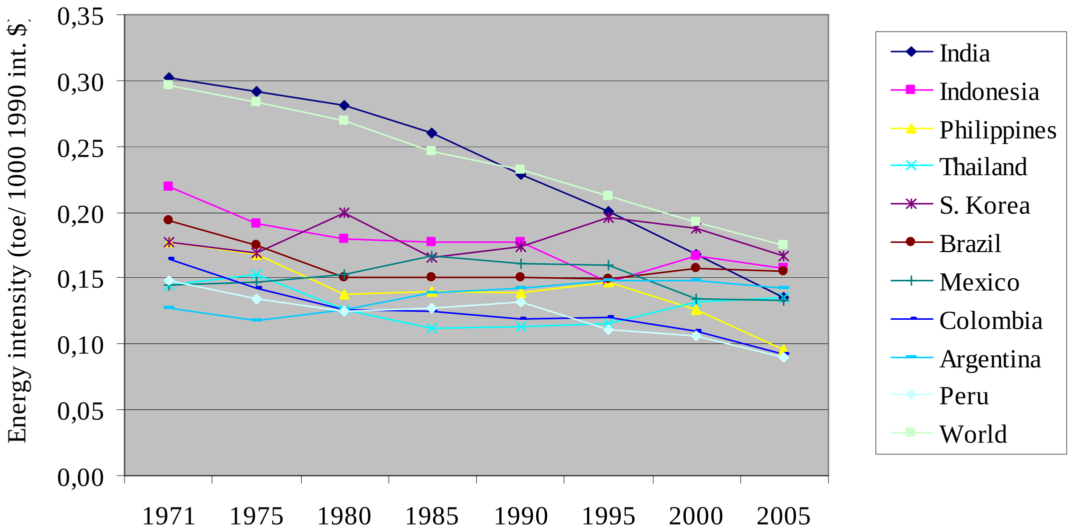
In addition to the role of the countries under study in the global economy, measured in economic terms (GDP), the historical examination of their energy consumption also stresses their importance as key determinants of the global as well as regional energy patterns. Since the beginning of the 1970s, Asian countries shares of the world energy consumption has almost doubled and today they make up almost 10% of the world's total energy consumption (see Tables A: 1 and A: 2 in the Appendix). Concerning their role in Asia (excluding China), in 2005, they were responsible for 82% of the region's energy consumption with India being the major energy consuming economy (in 2005 it accounted for 50% of the total energy consumption of our sampled economies). Almost of the same significance are the Latin American countries which today account for approximately 5% of the global energy consumption and 75% of that in their region. The biggest impact comes from the two major economies, namely Brazil and Mexico; in 2005 they accounted for almost 60% of the region's energy consumption.

With regards to the historical evolution of energy intensity (measured in toe/ 1000 1990 international dollars), the world as a whole has experienced a gradual and relatively steady decrease since 1971 (0.3 toe/ 1000 int. $), and by 2005 energy intensity had declined by 40% reaching at 0,18 toe/ 1000 int $ (Tables A: 1 and A: 2 in Appendix). When accounting for the regions included in the study, the data analysis shows that energy intensity has decreased in both regions, although in Latin America a relatively modest decrease took place during the last three decades (from 0.15 toe/ 1000 int. $ to 0.14 toe/ 1000 int. $). In contrast, the decrease in Asia was much bigger and equal to a total decline by almost 0,8 toe/ 1000 int. $ until 2005.

Concerning the countries that comprise our sample, in 1975 their average energy intensity was 0.17 toe/ 1000 int. $ with India being the more energy intensive economy (0.29 toe/ 1000 int. $) and Argentina being the relatively more efficient (0.12 toe/ 1000 int. $). As seen in Figure 3, that graphically presents the historical evolution of energy intensity for the ten developing countries as well as for the whole world, as these countries develop the average energy intensity of the sample decreases gradually. In detail, by 2005 it had declined by approximately 25% reaching at 0.4 toe/ 1000 int. $ which is less than the energy intensity of the global economy. In 2005 South Korea raises as the most energy intensive economy with its energy intensity exceeding even that of other relatively much bigger economies like India, Brazil and Mexico. Colombia and Peru were by far the less energy intensive countries (0.09 toe/ 1000 int. $).

Concerning the stylized EKC hypothesis, that as mentioned before implies an inverted U- shaped relationship between the level of GDP and energy consumption, the results for the ten countries examined here do not fully support it. Due to data restrictions, it is not possible to examine the period before 1971 that would enable to have a bigger perspective on the evolution of energy intensity. However, as shown in Figure 3, except for the case of India that demonstrates a constant downward curve after 1971 and resembles the global curve closely, for the rest of the countries, energy intensity does not decrease as sharply as the second half (after the 1980s) of the EKC hypothesis would imply. For India it can be argued that the curve has similarities with a U- shaped curve if we consider the peak to have taken place earlier.

Figure 3. Energy intensities in 10 developing countries, 1971-2005



Source: Own calculations based on data from IEA and Madison (2008)

On the contrary, for all nine countries there is a relatively stable, only slightly decreasing energy intensity (both before and after the 1980s) while when examining each country separately, each one demonstrates a fluctuating decrease (see Figure 3). Consequently, it could be argued that the first proposition of the hypothesis does not hold for the sample analyzed here.

Although, as seen in Figure 3, there is noticed a historically increasing tendency for convergence at a gradually smaller range of energy intensity that varies between 0.09- 0.17 toe/ 1000 int. $. This finding is in accordance to those of previous studies for developed and developing economies and suggests that the second part of the EKC hypothesis, that latecomers tend to leapfrog and reach lower peaks of energy intensity, is supported by the countries analyzed here. In fact, when converting energy intensity from toe/ 1000 1990 int. $ to MJ/ 1990 int. $ and compare the results to those for 10 developed economies, as analyzed in Henriques and Kander (2010) we see that this pattern of convergence does exist for the whole population. In detail, all twenty countries (ten developed from Henriques and Kander, 2010 and ten from the current study), in 2005 converged at very similar levels of energy intensity with the range varying from 5 to 10 MJ/ 1000 int. $. Furthermore it needs to be mentioned that, as stated in Henriques and Kander (2010), this "conspicuous feature" does not support the idea that developing countries today tend to be the factory of the world since this would suggest increasing energy intensities and a strong industrialization process, something that is not supported from the results.

5.2 Economic structures

After having provided a broad overview concerning the role of the ten developing countries under study in the global economy and their historical energy intensities' evolution, it is crucial to investigate how the economic structures of these economies have evolved. In particular, it is of great interest to investigate whether a service transition has taken place in these countries affecting energy intensity changes and furthermore analyze their industrialization processes focusing on changes that have occurred in their industrial sectors. Consequently, before moving to the decomposition analysis, the double hypothesis, established before, is tested here.

Concerning the first proposition, that the service sector has increased its shares of total employment and GDP when measured in current prices, the results presented in Table 1 fully support it for the whole sample of developing countries that are examined. Specifically, in terms of employment shares, available data for Brazil, Mexico and Colombia for the period 1950- 2005 show that their shares have more than doubled during these fifty five years while the biggest increase was observed in Brazil. In particular, the share of people employed in the economy's service sector more than tripled, as from 20% in 1950 it increased to almost 62% in 2005. Furthermore, when looking at the period 1971- 2005, for which data are available in all countries, we can also notice a significant increase in the number of people employed in services. More specifically, the average rate of increase for all ten economies was approximately 60% while in real terms, employment in the service sector in 2005 made

Table 1. Service sector shares of GDP (in current and constant prices) and Employment (in percentages)

Countries	Services (current prices)				Services (constant prices)				Employment (%)			
	1950	1971	1990	2005	1950	1971	1990	2005	1950	1971	1990	2005
India	23	29	38	50	23	30	39	51	n.a.	16	21	22
Indonesia	n.a.	35	40	40	n.a.	30	39	41	n.a.	24	33	40
Philippines	n.a.	34	40	50	n.a.	34	39	45	n.a.	35	41	48
Thailand	35	48	49	44	39	45	47	42	n.a.	18	25	39
S. Korea	33	41	42	45	59	54	44	41	n.a.	34	46	64
Brazil	n.a.	n.a.	60	54	48	52	58	56	20	33	51	62
Mexico	59	65	64	71	60	63	63	64	25	35	48	57
Colombia	41	45	46	52	43	47	48	53	27	41	50	58
Argentina	n.a.	n.a.	58	55	59	55	60	59	44	51	62	73
Peru	n.a.	n.a.	63	57	56	59	61	57	n.a.	33	51	52

Notes: services in constant prices are expressed in; 1993- 1994 prices for India, 2000 for Indonesia, 1985 for Philippines, 1988 for Thailand, 1986 for S. Korea, 2000 for Brazil, 1993 for Mexico and Argentina, 1994 for Colombia and Peru
Source: Timmer and de Vier (2007) and own calculations

up more than 50% for the majority of the countries. Available data for Thailand and South Korea in that period also demonstrate that these countries more than doubled their service employment shares.

In addition, measured in current prices, available data for the years 1950 and 1971 in seven countries show that the service sector has increased its share in GDP for all these economies (Table 1). In detail, the share of services has increased in average by a rate of 50% in these countries. As evident from Table 1, the larger increases are noticed in India, that during this fifty five year period (1950- 2005) more than doubled its shares of the sector, as well as in Philippines where since 1971 it increased at a rate of 70%. Consequently, it can be argued that in terms of employment and measurements in current prices the service sector did increase its share in all the economies in this fifty five year period. Perhaps more surprisingly, when compared to the service transition (in terms of employment) that took place in developed countries, the rate of increase for developing countries in the period 1970- 2005 is significantly larger. From data in Henriques and Kander (2010: 275) it is clear that the average growth of the people employed in services in ten advanced economies was 20 percentage units lower (it was 40%) compared to the countries examined here (60%). This feature possibly implies the fast development that these countries experience partly following the development patterns of more advanced economies.

Concerning the last hypothesis, which states that when measured in constant prices the share of the service sector does not necessarily increase that much (compared to increases in current prices), from the results in Table 1 it stems that it is largely supported but not unambiguously. As expected, for the majority of the countries, when measuring the service sector shares in real production terms, a relatively minor transition to services is noticed, signaling in that way that changes in energy intensity will largely be left unaffected by a transition to a service economy. In particular, for six of the countries examined here (Thailand, Brazil, Mexico, Colombia, Argentina, Peru) the transition to a service economy is extremely modest as the share of the service sector in the period 1950- 2005, either remains constant or increases relatively less than in current prices. In fact in the case of South Korea there is also noticed a strong industrialization process taking place since the share of services decreases significantly by 18%. Furthermore, there is noticed a geographical differentiation as the countries in Latin America show a relatively smaller transition to a service economy than in Asia. In fact, if we set the criteria for characterizing a case of "service transition" at 10%, a peculiar feature exists for three countries in Asia that actually increase their services in real production terms.

In detail, as shown in Table 1, India, Indonesia and Philippines stand out from the rest of the developing countries as they show a strong service transition in the period 1971- 2005. For the case of India, as stated in Henriques and Kander (2010), the most plausible explanation is that productivity in the service sector of the economy must have increased tremendously signaling a strong industrialization of its services since cost disease did not occur in part of the sector. The argument becomes even stronger if we account for changes in the shares of employment, that during these fifty years were relatively modest (increased only by 6% in India). The same argument of relatively more progressive services also stands, and maybe it is even stronger, for Indonesia as its service sector, in constant prices, increases significantly more (compared to the increase in current prices) and is also accompanied by a big increase in the share of people employed in the service sector. More specifically, in current prices the share of services increases by 6% while, when measured in real production terms, the increase is much bigger and reaches at 11% (see Table 1). Finally, for Philippines, there is noticed a strong service transition as well, however this is relatively weaker compared to the other two countries since the increase in constant prices, although above 10%, is still lower than the 17% increase, which occurred in current prices.

Given that there is noticed a modest growth of the service sector for the majority of countries in the sample, as well as a strong one for three of them, it is of interest to investigate

Table 2. Services subsectors, shares of sector's output in constant prices (in percentages)

Countries	1971				2005			
	Wholesale and retail trade (50-55)	Transport and communications (60-64)	Finance (65-74)	Public services (75-99)	Wholesale and retail trade (50-55)	Transport and communications (60-64)	Finance (65-74)	Public services (75-99)
India	41	17	7	35	34	22	16	27
Indonesia	48	10	6	36	41	15	21	22
Philippines	41	13	12	34	40	20	13	27
Thailand	53	16	7	25	41	26	8	25
S. Korea	25	8	9	58	31	30	7	33
Brazil	16	7	36	42	12	10	31	47
Mexico	41	11	5	43	37	23	8	32
Colombia	32	16	16	36	25	17	18	40
Argentina	40	13	7	41	32	20	8	40
Peru	40	11	14	35	36	16	18	30

Source: Timmer and de Vier (2007) and own calculations

the structural changes that occurred in the subsectors. As presented in Table 2, for all the countries in the sample, there is noticed a shift from relatively less energy intensive sectors, such as Wholesale and retail trade and Public services, towards Transports and communication. This fact is in accordance with the theory presented above and fully supports the idea that as these countries develop the need of basic infrastructures also increases and in that way such structural changes will tend to increase energy intensity. The average growth of the subsector, for all the countries since 1971, is almost 8% while South Korea demonstrates the stronger increase, as the sector's share increases almost by four times (from 8% in 1971 to 30% in 2005). Additionally, the industrialization of services, as discussed above, is also supported by these findings. Although almost all countries increase their shares in the Finance sector (a good example of industrializing services) for India and Indonesia, the increase is tremendously bigger. More specifically, since 1971 India's share of Finance in the value added of services more than doubled while in Indonesia it more than tripled (see Table 2).

Consequently, a transition to a service economy does not fully apply for the majority of developing countries and hence it is not expected to have any big impact on energy intensity changes. However, the peculiar features in the cases of India, Indonesia and Philippines could in some way affect their energy intensities.

Finally, since theory suggests that an industrialization process is under way for developing economies, it is of interest to investigate the within sector changes in industry and

Table 3. Industry subsectors, shares of sector's output in constant prices (in percentages)

Countries	1971				2005			
	Mining and Quarrying (10-14)	Manufacturing (15-37)	Public Utilities (40-41)	Construction (45)	Mining and Quarrying (10-14)	Manufacturing (15-37)	Public Utilities (40-41)	Construction (45)
India	8	60	6	27	8	63	8	21
Indonesia	67	25	0	8	21	64	2	13
Philippines	5	78	5	12	5	73	9	13
Thailand	3	72	4	21	5	82	7	6
S. Korea	7	57	2	33	0	77	6	17
Brazil	4	69	4	23	8	62	9	21
Mexico	4	73	4	19	5	73	7	16
Colombia	9	59	8	24	17	53	11	20
Argentina	4	70	3	23	6	62	11	22
Peru	20	64	3	13	23	53	7	17

Source: Timmer and de Vier (2007) and own calculations

analyze how they could affect energy intensity. As shown in Table 3, which presents the historical evolution of changes in the subsectors of industry, for all countries there is noticed a relatively large increase in the Public Utilities sector’s share. Although the sector does not hold the biggest share of industry in 2005, such an increase also depicts the growing demand that exists in these economies for basic infrastructures. Concerning relatively more energy intensive sectors, such as Manufacturing and Constructions, for the majority of the economies there is noticed a slight decrease in their shares while in other cases they almost remain constant holding the same shares. The only exception is the case of Indonesia; since 1971 the Manufacturing sector’s share in total value added of industry has more than doubled, signaling that within sector changes would increase energy intensity, unless more efficient technology is being imported (the leapfrogging proposition)

5.3 Decomposition analysis

After having performed the initial analysis of the structural changes that have occurred both between as well as within sectors, in order to investigate in a tentative way the impact of such changes on energy intensity, we move to the results from the decomposition calculations. The results will allow for a more thorough examination of the role of structural versus technical change and will also highlight the effect of households' energy consumption on the energy intensity decline.

Tables A: 3 and A: 4 in the Appendix present the data that were used in the LMDI decomposition for the years 1971, 1990 and 2005 for Asian and Latin American countries respectively. In detail, for all countries, the shares of sectors in Gross Value Added (GVA) and total energy consumption are presented, as well as the relative energy intensities of each sector. The most interesting feature is the decreasing importance of Agriculture for all the countries in favor of the other sectors with the greater increase occurring, on average, in the years before 1990. India and Indonesia seem to follow the same patterns when accounting for the whole period, as both of them present a significant shift from Agriculture towards both Industry and Services. However, South Korea, Thailand and Mexico stand out by having the strongest industrialization as the economies clearly shift from agricultural production towards industry. Particularly in the case of South Korea, since 1971, the share of Agriculture decreases by almost 80% while Industry more than doubles its share in GVA. The rest of the economies (Philippines, Brazil, Colombia, Argentina and Peru) present minor or no changes in their industrial production shares.

Furthermore, the majority of the economies demonstrate an average decrease of almost 50% in the share of energy consumption by the residential sector while Indonesia is the only country that starts from extremely high shares in 1971 (85%). These finding are in accordance with Henriques and Kander (2010) for India, Mexico and Brazil and signal that as these countries grow, the swift from traditional energy fuels as well as the decreasing share of the residential sector leads to decreases of energy consumption. As stated in Watchman et al. (2004), one of the reasons for the decline in per capita energy use of the Brazilian households during the period 1970- 1995 was the swift from relatively inefficient energy carriers, such as firewood, towards more energy efficient fuels, such as the LPG (in fact, one toe of Liquid Petroleum Gas can substitute 7- 10 toe of firewood as gas fired stoves are more efficient). However, it needs to be noted that since energy consumption data for personal transportation are included in the transportation sector and not in the residential sector, this decrease could partly be overestimated.

Finally, concerning their energy intensities, calculated in each country's constant national currency, the greater decrease, as seen in the overview analysis, occurs for India (of approximately 60%) after which follow Philippines, Indonesia, Colombia and Peru with a decrease varying between 40% and 45%. Additionally, Thailand, South Korea, Brazil and Mexico demonstrate significantly smaller decreases (vary between 8% and 23%). Argentina stands out as the only economy that increases its energy intensity significantly during the whole period (1971- 2005) and this is mainly driven by the rise of energy intensity in the period 1971- 1990 by 24%.

In Tables 4 and 5, the results from the decomposition analysis of energy intensity for the developing countries dataset are presented. When accounting for the sample as a whole and examining the relative effect of structural versus technical change, it is clear that on average, for all countries, the impact from both effects tends to be almost the same (about 20%). However, each impact drives total energy intensity towards different directions. More explicitly, during the period 1971- 2005, technological changes in the productive sectors of the majority of economies, worked in the direction of decreasing energy intensity. The only exception is the case of Indonesia whose productive sectors' intensity changes tend to increase total energy intensity by 10% with the biggest part occurring in the period before the 1990s (see Table 4). This effect is mainly attributed to within Industry changes that occurred in the country and as mentioned above, implied a tremendous growth of the Manufacturing sector, which probably was not accompanied by significant efficiency improvements (for instance through imports of technologically advanced machinery) (see Table 3).

On the other hand, the direction of structural changes in the period 1971- 2005, tended to increase energy intensity in all countries with the main increase taking place in the period after the 1990s. These structural changes reflect the rising share of Transport and communications in these economies that tended to increase energy intensity. From Table 5, it is evident that the biggest impact of the growing Transport and communications sector is noticed in Mexico as it accounted for almost all of the structural changes in the economy and contributed to the increase of energy intensity by 35%. Generally, the impact from the service sector is relatively modest in all the economies while in the countries where an industrialization of the service sector was noticed (mainly India and Indonesia), its effects on energy intensity are unambiguous. For India the whole process seems to have been accompanied by efficiency improvements in the sector since the intensity changes in services contributed by a 7% decrease in total energy intensity. In contrast for Indonesia, the relatively larger rise of the Finance sector was possibly not accompanied by efficiency improvements, increasing in that way energy intensity by 3% (see Table 4).

Finally, concerning the role of the residential sector, it is of great significance to the decreases of energy intensity for the whole sample. On average, in the period 1971- 2005, it contributed to almost 40% decrease. This feature signals that even if data allowed us to account for energy consumption by personal transportation the contribution of the residential

Table 4. Divisia decomposition 1971- 2005, for Asian countries

Sectors	Changes	India			Indonesia			Philippines			Thailand			S. Korea		
		1971/ 1990	1990/ 2005	1971/ 2005	1971/ 1990	1990/ 2005	1971/ 2005	1971/ 1990	1990/ 2005	1971/ 2005	1971/ 1990	1990/ 2005	1971/ 2005	1971/ 1990	1990/ 2005	1971/ 2005
Agriculture	Intensity	1.01	1.02	1.03	1.01	1.01	1.02	0.98	0.99	0.97	1.02	1.01	1.03	1.02	1.00	1.01
	Structure	0.99	0.99	0.98	0.99	0.99	0.99	1.00	1.00	0.99	0.95	0.98	0.94	0.98	0.99	0.97
Industry	Intensity	0.92	0.86	0.80	1.15	0.96	1.13	1.00	0.93	0.94	0.81	1.05	0.82	0.72	0.92	0.65
	Structure	1.06	1.01	1.07	1.02	1.02	1.03	1.00	0.98	0.99	1.13	1.08	1.23	1.33	1.05	1.41
Services	Intensity	0.97	0.97	0.93	1.00	1.01	1.01	1.02	1.02	1.03	1.01	1.05	1.05	1.15	1.04	1.19
	Structure	1.01	1.01	1.02	1.00	1.00	1.00	1.00	1.00	1.01	1.00	0.99	0.99	0.97	0.96	0.95
Transportation	Intensity	0.94	0.89	0.85	0.96	0.98	0.94	0.86	0.91	0.75	1.02	0.92	0.95	1.00	0.85	0.88
	Structure	1.04	1.05	1.09	1.05	1.05	1.10	1.07	1.13	1.24	1.02	1.10	1.10	1.10	1.15	1.24
Productive sectors	Intensity	0.85	0.76	0.65	1.12	0.96	1.10	0.86	0.85	0.72	0.85	1.02	0.85	0.85	0.81	0.69
	Structure	1.10	1.05	1.16	1.06	1.07	1.12	1.07	1.12	1.23	1.10	1.15	1.27	1.38	1.14	1.59
Residential	Pers. Cons	0.78	0.73	0.56	0.55	0.83	0.45	0.84	0.73	0.62	0.82	0.90	0.75	0.88	0.92	0.80
Total Energy Intensity Change		0.73	0.59	0.42	0.65	0.85	0.55	0.78	0.70	0.54	0.77	1.05	0.81	1.03	0.85	0.88

Note: The value of 1 means no change; 1.12 means 12% increase of total final energy intensity; 0.90 means 10% decrease of total final energy intensity
Source: own calculations based on data from Timmer and de Vier (2007) and IEA

Table 5. Divisia decomposition 1971- 2005, for Latin American countries

Sectors	Changes	Brazil			Mexico			Colombia			Argentina			Peru		
		1971/ 1990	1990/ 2005	1971/ 2005	1971/ 1990	1990/ 2005	1971/ 2005	1971/ 1990	1990/ 2005	1971/ 2005	1971/ 1990	1990/ 2005	1971/ 2005	1971/ 1990	1990/ 2005	1971/ 2005
Agriculture	Intensity	0.97	0.99	0.96	1.01	1.00	1.01	1.05	0.99	1.04	1.01	1.03	1.04	0.92	0.98	0.89
	Structure	0.98	1.01	0.99	0.99	0.99	0.98	1.00	0.99	0.99	1.01	1.00	1.00	1.00	1.00	1.00
Industry	Intensity	0.99	1.09	1.07	0.97	0.89	0.86	0.89	0.98	0.86	1.08	1.02	1.11	0.97	0.97	0.93
	Structure	0.97	1.01	0.98	1.04	1.00	1.03	1.01	0.99	1.00	0.95	1.01	0.96	0.99	1.03	1.01
Services	Intensity	1.01	1.02	1.02	1.00	1.02	1.02	1.00	1.00	1.00	1.06	0.98	1.04	1.01	0.99	1.00
	Structure	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.99	1.00	1.00	1.00	1.00
Transportation	Intensity	0.88	1.03	0.90	0.96	0.85	0.83	1.00	0.89	0.91	0.97	0.85	0.81	0.96	0.91	0.88
	Structure	1.11	1.03	1.14	1.14	1.18	1.35	1.02	1.04	1.06	1.06	1.12	1.20	1.07	1.01	1.08
Productive sectors	Intensity	0.84	1.14	0.94	0.94	0.77	0.74	0.94	0.86	0.82	1.12	0.88	0.98	0.86	0.87	0.73
	Structure	1.05	1.05	1.10	1.17	1.17	1.36	1.03	1.02	1.05	1.02	1.12	1.15	1.05	1.04	1.10
Residential	Pers. Cons	0.74	0.98	0.75	0.97	0.95	0.92	0.78	0.84	0.65	1.09	0.99	1.07	0.95	0.78	0.74
Total Energy Intensity Change		0.66	1.17	0.77	1.07	0.86	0.92	0.75	0.74	0.56	1.24	0.98	1.21	0.85	0.70	0.60

Note: The value of 1 means no change; 1.12 means 12% increase of total final energy intensity; 0.90 means 10% decrease of total final energy intensity
Source: own calculations based on data from Timmer and de Vier (2007) and IEA

sector, although lower, would still be significant determining declines in total energy intensity. Exception is Argentina where the residential sector's energy consumption patterns were responsible for 9% of the total energy intensity increase in the period 1971- 1990.

However, the effects of structural and technical changes are not of the same significance for all countries and this gives reason to examine some countries separately and see whether they can be grouped in different cohorts that follow the same patterns. Actually, for four out of ten countries (India, Philippines, Colombia and Peru) the technical changes that occurred during the period 1971- 2005 clearly offset the increases caused by the structural changes in these economies. In particular, for India and Colombia the technological effect is mainly driven by changes that have occurred in their industry and have contributed to a 20% and 14% decrease of total energy intensity respectively. Except for the within- sector changes, which correspond to the rising share of Public Utilities, such technical changes give reason to believe that this also reflects efficiency improvements. The reason is that in India the share of the Manufacturing sector (see Table 3) also increases significantly and one would expect that per se, it would lead to increases of energy intensity. Additionally, as shown in Table 3, in the case of Colombia the relatively energy intensive sector of Mining and Quarrying also increases (by 80% in Table 3) however efficiency improvements manage to drive down the energy intensity of industry. Consequently, for these economies, the energy intensity decrease was mainly driven by technological changes, possibly favored by international trade and the import of energy efficient machinery. Such changes occurred in both industry and transportations, while the decrease was further reinforced by the contribution of the residential sector.

On the other hand, for Indonesia, Thailand, South Korea, Brazil and Mexico (Tables 4 and 5), structural changes clearly offset within- sector changes and tend to increase energy intensity. In contrast to the countries examined before, for these economies, the industrialization process along with the rising share of Transport and communications, clearly offset possible efficiency improvements and leads to energy intensity increases. The most significant cases are that of South Korea and Thailand, where an extremely strong industrialization is taking place, which, however, is not accompanied by sufficient efficiency improvements or such within- industry changes that would allow for decreases in total energy intensity for these economies. Especially for the case of South Korea, the industrialization process along with the rising share of the Transport and communication sector have a relatively stronger effect on energy intensity, than in other economies, since together they tend to increase it by almost 55% (see Table 4). As a result, the main contribution to the total decline of energy intensity for these countries is primarily done by the non productive economy, namely, the residential sector. However, the same does not hold for Argentina since structural changes along with the contribution by the residential sector clearly drive the rise of the country's energy intensity.

6 Conclusion

The current study aimed at decomposing the energy intensity patterns for ten developing countries in Asia and in Latin America into structural and technical changes that took place in these economies during the last 35 years. For all the countries examined, specifically from 1971 to 2005, energy intensity has decreased, with the only exception of Argentina. However, this decreasing trend does not follow a steep decline after the 1980s, as the stylized EKC (U- shaped curve) would suggest, but it is rather characterized by a gradual and fluctuating decrease for the majority of the countries. Furthermore, the fact that all these countries converge within a smaller range of energy intensity with more advanced economies, clearly supports the results from previous studies and signals that on that basis developing countries do not get the role of being the factory of the world today.

However, the results of the study suggest that these decreasing trends of energy intensity do not imply that the development patterns of these economies automatically lead to significant alleviations for the environment. In fact, it could be argued that so far, the developing countries have not managed to absorb the merits accompanied by the third Industrial Revolution unanimously. For all of them a relatively big contribution to the decline of total energy intensity is done by the changes that have occurred in these economies' household sector and contributed to the changes that occurred in the productive economy. However, big differentiations are traced among the sampled economies examined in this study in terms of their structural changes and more importantly concerning the role of technical changes that have occurred in their productive sectors. A transition to a service economy, in real production terms, is extremely modest for the majority of the countries and only for India contributes modestly to decreases of total energy intensity. Additionally, for Indonesia, although a service transition has taken place, this does not contribute to any decrease of energy intensity, because in contrast to India, the increase of the Finance sector in the country seems to be relatively less productive and so it is not accompanied by adequate efficiency improvements. Finally, the industrialization process is of unambiguous significance among the countries with South Korea, Thailand and Mexico presenting the strongest industrialization that weights out any technological changes in industry and per se, tends to increase total energy intensity.

In general, the countries examined can be distinguished in two different cohorts according to the relative effect of structural and technical changes in the productive economy. The first group is comprised by India, Philippines, Colombia and Peru for which technical changes (within- sector changes) were the main determinants of the decline in total energy intensity while their contribution was further reinforced by the residential sector. Furthermore, the results suggest that for the cases of India and Colombia, these technical changes do not only suggest a movement into lighter manufacturing but also significant upgrading of inefficient production processes. On the other hand, for Indonesia, Thailand, South Korea, Brazil and Mexico, the main contribution to the actual fall in energy intensity did not come from the productive economy but rather from the residential sector in these countries. Structural changes, and specifically a strong industrialization process along with the rising demand of basic infrastructures, clearly offset possible efficiency improvements in these countries and per se tended to increase total energy intensity.

The most significant outcome of the study is that the establishment of relatively more energy efficient production processes is not a generalized phenomenon that occurs evenly and to the same degree in all developing countries. In fact, as has been shown, some of them seem to be on the right way, since efficiency improvements are taking place in their industries, while for others further policies need to be implemented that would lead to the upgrading of their productive economies and consequently could lead to more meaningful decreases of total energy intensity. Those countries that in this thirty five year period had the strongest industrialization seem to be the ones that need further improvements in their infrastructures while for others, their industrialization process seem to follow more “sustainable” patterns. Finally, the rising share of the Transport and communication sector in all these countries, and its distinct role as a driver of increases in total energy intensity, designates that this is one of the most significant challenges that all developing countries will have to tackle today. It creates the demand for more effective policies that will manage to cope with challenges related with the increasing urbanization processes and the relatively poor public transportation networks that characterize these economies.

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Appendix

Table A: 1. Values of GDP, Energy consumption and Energy intensity of selected countries, 1971-1985

	1971			1975			1980			1985		
Country	GDP (PPP) 1990 million int. $	Total final energy consumption (ktoe)	Energy intensity toe/mil. $	GDP (PPP) 1990 million int. $	Total final energy consumption (ktoe)	Energy intensity toe/mil. $	GDP (PPP) 1990 million int. $	Total final energy consumption (ktoe)	Energy intensity toe/mil. $	GDP (PPP) 1990 million int. $	Total final energy consumption (ktoe)	Energy intensity toe/mil. $
World	14336492	4256252	0.30	16637925	4714863	0.28	20029995	5387367	0.27	22969599	5641508	0.25
Asia	3367298	638233	0.19	4133549	756270	0.18	5232929	912214	0.17	6646374	1060227	0.16
India	474338	143123	0.30	544683	158578	0.29	637202	179281	0.28	814344	211461	0.26
Indonesia	146200	32071	0.22	196374	37584	0.19	275805	49648	0.18	323451	57361	0.18
Philippines	71799	12753	0.18	90150	15159	0.17	121012	16629	0.14	113493	15950	0.14
Thailand	65886	9519	0.14	82799	12702	0.15	120116	15115	0.13	156598	17537	0.11
South Korea	76695	13605	0.18	111548	18851	0.17	156846	31287	0.20	231386	38227	0.17
L. America	1208086	183610	0.15	1517433	226490	0.15	1960037	284197	0.14	2029889	308927	0.15
Brazil	322159	62539	0.19	455918	79733	0.17	639093	96160	0.15	675090	101816	0.15
Mexico	237480	34335	0.14	312998	46131	0.15	431983	65921	0.15	475505	79065	0.17
Colombia	70250	11569	0.16	87347	12411	0.14	113375	14343	0.13	127076	15851	0.12
Argentina	183458	23284	0.13	211850	25074	0.12	232802	29365	0.13	209641	29183	0.14
Peru	53131	7890	0.15	65587	8829	0.13	73727	9163	0.12	71239	9034	0.13

Source: Madisson (2008), IEA and own calculations

Table A: 2. Values of GDP, Energy consumption and Energy intensity of selected countries, 1990-2005

	1990			1995			2000			2005		
Country	GDP (PPP) 1990 million int. $	Total final energy consumption (ktoe)	Energy intensity toe/mil. $	GDP (PPP) 1990 million int. $	Total final energy consumption (ktoe)	Energy intensity toe/mil. $	GDP (PPP) 1990 million int. $	Total final energy consumption (ktoe)	Energy intensity toe/mil. $	GDP (PPP) 1990 million int. $	Total final energy consumption (ktoe)	Energy intensity toe/mil. $
World	27134084	6292529	0.23	30942239	6555996	0.21	36688285	7044688	0.19	44982587	7882745	0.18
Asia	8642381	1287934	0.15	11477064	1552693	0.14	13694593	1655797	0.12	18807606	2122519	0.11
India	1098100	251694	0.23	1425623	285960	0.20	1899526	318579	0.17	2649687	358235	0.14
Indonesia	450901	79842	0.18	656101	96097	0.15	697849	116585	0.17	846938	133127	0.16
Philippines	143025	19912	0.14	159264	23364	0.15	193066	24258	0.13	240215	23099	0.10
Thailand	255732	28879	0.11	387097	44838	0.12	395791	51955	0.13	506141	68255	0.13
South Korea	373150	64907	0.17	534517	104683	0.20	673289	126386	0.19	839757	140180	0.17
L. America	2239815	335760	0.15	2647621	382856	0.14	3066779	435512	0.14	3495796	480407	0.14
Brazil	743765	111567	0.15	866086	129578	0.15	975444	153987	0.16	1110868	171856	0.15
Mexico	516692	82887	0.16	557419	89117	0.16	726934	97880	0.13	797691	105699	0.13
Colombia	159042	18919	0.12	196567	23664	0.12	202230	22090	0.11	242124	22351	0.09
Argentina	212518	30185	0.14	282653	42002	0.15	320364	47321	0.15	353381	50095	0.14
Peru	64979	8560	0.13	86070	9538	0.11	99573	10604	0.11	122088	10982	0.09

Source: Madisson (2008), IEA and own calculations

Table A: 3. Sector shares of Gross Value Added and energy consumption and energy intensities for Asian countries, 1971- 2005

Sectors	India			Indonesia			Philippines			Thailand			South Korea		
	1971	1990	2005	1971	1990	2005	1971	1990	2005	1971	1990	2005	1971	1990	2005
	Sector share of total GVA (%)														
Agriculture	47	33	21	34	20	15	29	24	20	28	14	10	24	9	5
Industry	23	28	29	35	41	44	37	38	35	27	39	48	22	47	54
Services	25	32	40	27	34	35	29	33	36	38	39	31	50	37	29
Transportation [a]	5	7	11	3	5	6	5	6	9	7	8	11	4	7	12
	Share of energy consumption (%)														
Agriculture	1	2	4	1	1	2	3	2	1	7	6	6	3	3	2
Industry	25	30	33	5	27	30	18	24	23	32	30	40	40	34	36
Services	5	4	4	0	1	3	2	4	9	2	4	7	4	15	18
Transportation [b]	10	12	11	8	14	20	25	24	37	21	32	31	16	25	27
Residential	59	52	49	85	56	45	52	47	30	38	28	16	36	23	17
	Energy intensity 100= Total for 1971														
Total	100.0	72.6	42.5	100.0	65.1	55.3	100.0	77.8	54.4	100.0	76.7	80.9	100.0	103.3	87.9
Agriculture	10.1	24.7	41.2	0.0	5.7	11.1	40.4	18.7	11.7	51.3	69.1	85.1	0.3	0.8	0.7
Industry	516.5	373.9	232.5	0.2	0.6	0.5	176.6	180.2	131.9	233.8	117.7	134.4	4.3	1.7	1.4
Services	91.9	43.8	19.2	0.0	0.0	0.1	19.8	37.5	48.7	10.5	14.0	34.0	0.2	1.0	1.3
Transportation	967.4	546.8	199.3	3.6	2.6	2.3	2078.5	1121.9	810.8	565.6	614.0	469.8	8.6	8.8	4.6

Source: Timmer and de Vier (2007), IEA and own calculations

Table A: 4. Sector shares of Gross Value Added and energy consumption and energy intensities for L. American countries, 1971- 2005

Sectors	Brazil			Mexico			Colombia			Argentina			Peru		
	1971	1990	2005	1971	1990	2005	1971	1990	2005	1971	1990	2005	1971	1990	2005
	Sector share of total GVA (%)														
Agriculture	9	7	8	10	7	6	21	18	15	7	8	7	10	10	10
Industry	38	35	36	27	30	30	32	33	32	38	32	34	31	30	33
Services	49	53	50	56	53	50	40	40	44	48	52	47	52	52	48
Transportation [a]	3	5	5	7	10	15	7	8	9	7	8	12	7	9	9
	Share of energy consumption (%)														
Agriculture	9	6	5	4	3	3	2	7	7	4	5	8	11	4	4
Industry	29	39	42	38	36	28	31	28	35	35	30	35	23	22	32
Services	2	5	6	2	2	4	3	4	5	4	9	7	2	3	4
Transportation [b]	24	32	33	32	39	46	21	30	32	38	34	29	21	27	29
Residential	36	18	14	25	20	18	44	30	21	18	22	21	42	43	31
	Energy intensity 100= Total for 1971														
Total	100.0	65.9	77.1	100.0	107.0	92.4	100.0	75.4	55.7	100.0	124.1	121.2	100.0	85.2	59.7
Agriculture	1664.6	1029.2	866.2	254.9	317.1	362.2	0.4	1.4	1.2	973.6	1331.8	2030.8	1538.4	517.1	346.0
Industry	1377.1	1331.9	1648.2	1003.0	912.3	630.7	4.6	3.1	2.9	1410.3	1785.5	1925.9	1044.3	902.6	808.4
Services	84.6	102.6	154.4	22.6	29.1	49.8	0.3	0.3	0.3	130.4	328.7	266.3	63.6	77.4	64.6
Transportation	12407.9	7767.4	8531.2	3336.6	3007.2	2071.5	13.4	13.6	9.4	8431.2	7708.9	4577.6	4437.7	3663.9	2651.9

Source Timmer and de Vier (2007), IEA and own calculations