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Energy efficiency in developing countries for the manufacturing sector

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I. Synthesis: Energy efficiency in developing countries for the manufacturing sector

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Abstract

The Overseas Development Institute (ODI) developed a series of papers contributing to the UNIDO Industrial Development Report 2011. The papers were structured in 4 different studies:

Paper 1) ***An econometric study about the link between energy intensity levels (dependant variable) and total factor productivity (independent variable)*** by using the World Bank Enterprise Survey in 24 developing countries. A second section of this paper investigates the existence of the Environmental Kuznets Curve (represented by a bell shaped relationship) between income per capita and energy per capita.

Paper 2) ***An econometric analysis about the relationship between profitability (dependant variable) and energy intensity (independent variable)*** in developing countries by using the World Bank Enterprise Survey.

Paper 3) ***A decomposition analysis to discriminate energy efficiency and structural change components of the energy intensity shifts over time at the macroeconomic level by using the UNIDO INDSTAT 4*** data for value added and the International Energy Agency data for energy consumption for 20 developing countries. This study represented a useful background for a subsequent study employing the UNIDO INDSTAT2 dataset for 59 developing and developed countries led by Smeeta Fokeer with the advisory activity of Nicola Cantore.

Paper 4) ***A discrete choice analysis to investigate factors determining the adoption of energy efficiency technology in developing countries*** through data collected by UNIDO questionnaires in Moldova, Singapore, Viet Nam and Thailand. The econometric analysis was inspired by a previous ODI background paper setting the criteria for the model implementation.

The main results can be summarized by the following statements:

1) Through parametric and non-parametric estimations, we find evidence of a strong negative correlation between energy intensity and total factor productivity. In other words, we find that the most innovative firms are those showing the lowest levels of energy intensity for 23 out of 24 countries. We do not have sufficient evidence to show that the causal relationship goes from technological change to energy efficiency or rather the other way around (or both).

2) We do not find robust evidence of the EKC existence for energy per capita. Only for 10 out of 24 countries we provide evidence of the existence of a turning point in the relationship between energy per capita and income per capita. Only in a few developing countries firms are following a growth path where the level of energy per capita at a certain point endogenously decreases without the need of specific energy reduction policies.

3) Through a fixed effect econometric model we find for 27 countries that a lower level of energy intensity increases profitability. For 13 countries this relationship is also significant (0,05 significance level) from a statistical point of view. Only for 2 countries we find a positive but not significant coefficient expressing the relationship between energy intensity and profitability. The fixed effect estimation technique partially mitigates the suspect of endogeneity bias.

4) The decomposition analysis shows that the majority of developing countries investigated in our analysis (14 out of 20) show an improvement in energy efficiency. The majority of developing countries (14 out of 20) show an economic structural change towards energy intensive manufacturing sectors during the growth path. These results are then confirmed by the analysis driven by using INDSTAT2 rather INDSTAT 4 data with 59 countries.

5) The discrete choice analysis run through 116 observations shows that management and organization factors especially matter in explaining future choices of firms in developing countries to invest in energy efficiency rather macroeconomic factors. Moreover firms that already invested in energy efficiency are more likely to do it again in the future.

In this paper we will discuss these findings in the light of the relevant literature and with an integrated perspective.

Introduction

The promotion of environmental global public goods is one of the most pressing global challenges, with a profound impact on development. A look at the literature reveals that global public goods tend to be underprovided. And when it comes to climate change, polluting countries do not pay enough, while some actors 'free ride' when they enjoy the benefits of clean environment without bearing the costs. Investment in energy efficiency (EE) represents one of the most promising avenues to address climate change – such measures represent a win-win situation, reducing emissions while safeguarding productivity and incomes in poor countries.

In spite of the relevance of EE from an environmental point of view a very important research question is to investigate the impact of EE on the economic growth in both a micro and macro perspective. A series of ODI studies specifically analyse the link between EE, profitability and innovation and determinants of EE technology adoption in developing countries. This document summarizes ODI findings in a few paragraphs within the broad context of the whole set of findings coming from ODI research contributing to the UNIDO Industrial Development Report (IDR) and of the recent literature. The paper is organized as follows. In the section 2 we explain the results linking energy intensity and profitability for different countries. In the section 3 we will briefly explain results about the relationship between innovation and energy intensity. Finally in the section 4 we will comments findings about developing countries firms` barriers to invest in EE technology.

1. Does energy efficiency pay? Profitability and energy efficiency in different countries and sectors

An interesting research question arising from the existing literature is whether EE improvements ***contribute*** to boosting profits of firms in developing countries. ODI develops a study **(Paper 2)** using data from the World Bank Enterprise Survey of 29 developing countries. The profit is calculated as price cost margin (value of sales net of manpower costs and raw materials). In the basic model, profits depend on EE and dummy variables for countries and industries[1]. Model specifications differ according to the presence of firms` fixed effects (column 4 and 5), and further firms` characteristics such as the value of capital, number of workers, age of the firms etc. (column 2 and 3 and 5*).*

[1] For further details, see Paper 2.

Table 1 Profitability and Energy efficiency

	(1)		(2)	(3)	(4)		(5)
	Coeff	SE	Coeff	Coeff	Coeff	SE	Coeff
Bangladesh	0.59***	(0.14)	0.72***		-0.13	(0.14)	-0.19
Benin	-0.17	(0.17)	-0.10		-0.80	(0.60)	
Brazil	-0.54***	(0.10)	-0.51***	-0.51***	-0.41***	(0.11)	-0.40***
China	0.11	(0.20)	0.12		-0.64***	(0.25)	
El Salvador	0.08	(0.15)	0.15	0.15	0.12	(0.16)	0.11
Eritrea	-1.91**	(0.75)	-2.18**	-2.91***	-3.50***	(1.35)	-2.62
Ethiopia	-0.40**	(0.19)	-0.34*	-0.35*	-0.48	(0.32)	-0.70
Guatemala	-0.15	(0.10)	-0.15	-0.15	-0.77***	(0.21)	-0.83***
Honduras	-0.22*	(0.12)	-0.25*	-0.24*	-0.28**	(0.12)	-0.27**
India (2000)	0.08	(0.10)	0.00		-0.24	(0.27)	0.08
India (2002)	-0.20***	(0.07)	-0.20***		-0.27*	(0.14)	-0.11
Indonesia	-0.00	(0.06)	0.01		-0.43***	(0.13)	
Kenya	0.37***	(0.10)	0.42***		-0.11	(0.09)	
Madagascar	-1.53***	(0.19)	-1.50***	-0.83**	-2.67***	(0.99)	-1.78
Malawi	-0.42**	(0.17)	-0.38**	-0.40**	-0.98**	(0.41)	-0.99**
Mali	-0.22	(0.50)	0.65*		-0.53	(0.60)	
Mauritius	-0.30***	(0.10)	-0.28***	-0.34***	0.02	(0.12)	0.05
Morocco	-0.23**	(0.09)	0.00		-0.51**	(0.21)	-0.43**
Mozambique	-0.25	(0.16)	-0.17		-0.75	(1.19)	
Nicaragua	-0.01	(0.12)	-0.03	-0.04	-1.60***	(0.30)	-1.56***
Pakistan	0.08*	(0.04)	-0.22	-0.14	-0.11***	(0.04)	0.00
Philippines	0.41***	(0.09)	0.44***	0.45***	-0.35*	(0.18)	-0.37*
Senegal	-0.87***	(0.22)	-0.81***		-1.24***	(0.21)	
South Africa	0.19	(0.31)	0.27	0.39	-3.41***	(1.18)	-3.57**
Sri Lanka	-0.35***	(0.11)	-0.38***		-0.51*	(0.29)	
Tanzania	0.27*	(0.16)	0.13	0.51	0.07	(0.08)	-0.02
Thailand	0.31***	(0.07)	0.34***	0.16	-0.26	(0.27)	0.05
Uganda	0.39***	(0.09)	0.40***		-0.01	(0.12)	
Viet Nam	0.79***	(0.08)	0.81***	0.84***	-0.14	(0.11)	-0.21
Zambia	0.10	(0.34)	0.02	-0.03	-1.19	(0.74)	-1.15
Age (ln)			0.01***	0.01***			
Workers (ln)			0.01***	-0.00			-0.02
Equipm (ln)				0.01***			-0.01*
Exporter			0.01***	0.02***			
Foreign			0.02***	0.02***			
ISO				0.01			
Work sq (ln)							0.00
Eq. sq. (ln)							0.003*
Fixed eff.							
Industry-year	YES		YES	YES	YES		YES
country-year	YES		YES	YES	YES		YES
Firms	NO		NO	NO	YES		YES
Observations	40781		31635	15296	40781		24523
Adj. R-sq.	0.093		0.101	0.088	0.754		0.749

*Robust standard errors in parentheses; * significant at 10%; ** significant at 5%; *** significant at 1%. The dependent variable is value added net of labour costs over total sales value. The value for each country indicates the value of the coefficient of energy intensity in the different specifications.*

The most interesting results are contained in column 4 and 5 presenting results for a model including firms` fixed effects. As shown by column 4 of Table 1, results reveal that for 27 out of 29 countries, the sign of the relationship between EE and profitability is negative. For 13 out of 29 countries, the relationship is negative and significant at a 0.05 significance level.

In column 5 including firms` fixed effects and other firms` characteristics such as the number of workers and the value of equipment, the reader may notice that for 16 out of 21 countries, the sign of the relationship between EE and profitability is negative and for 7 countries the coefficient is significant.

Hence, results suggest that EE may increase firms` profitability in many circumstances and this finding is confirmed by many studies in the current literature. The energy economics literature has widely emphasized that EE provides many monetary non-energy benefits. A survey of 77 projects in 6 OECD countries, Worrel et al. (2003) find 224 different non-energy benefits that were cited in the 77 case studies included in their paper. The most cited benefits in terms of cost reduction observed under the heading of waste/materials reductions are reductions in materials (12 cases), followed by reductions in water used (five cases). The most common benefit cited in the improved maintenance and operation category was lower costs from reduced equipment wear and tear (20 cases). Reductions in required labour costs were noted in eight cases. Non-energy benefits categorized as other include reductions in noise (five cases), and improved worker morale (two cases). Worrel et al. also calculate that for 55 projects the average payback rate to be 1.9 years when considering energy and non-energy benefits (as included in Table 1).

Table 2 Profitability of energy efficiency projects

Total project investment	54179060$
Total annual energy savings	19233255$
Total annual productivity savings	15695582$
Combined total savings	28493331$
Average energy payback	4.2 years
Average payback including energy and non energy benefits	1.9 years

Source: Worrel et al. (2003)

At macroeconomic level, Jian (2009) runs a regression model of China's real output to capital, labour and EE to estimate the marginal contribution of every factor to the real output and proves the fundamental influence of EE to the economic growth. In the IDR 2011 chapter addressed to investigate the energy intensity movements decomposition Fokeer and Cantore show that regions with the highest level of income are characterized by the lowest level of energy per capita. A relationship between EE and relevant output growth rates increases is also emphasized by the theoretical modelling literature (Wei, 2006).

In spite of this micro and macroeconomic evidence showing a link between EE and profitability our results do not support the existence of a strong relationship between these variables in all countries. ***If we look at column 4 and 5 of Table 1, the link between the energy intensity level and profits is not negative or significant in many countries. This heterogeneity can also be observed at sector level. Table 3 shows that according to sector specific regressions for the manufacturing sectors, only 9 out of 15 sectors have a negative and significant sign, expressing the impact of profitability on energy intensity.***

Table 3 Profitability and energy efficiency, regressions by industry

	Coeff.	S.E.	Obs	Firms	R-sq.
Textiles	-0.221***	(0.070)	5267	2,016	0.023
Leather	-0.229*	(0.125)	1612	621	0.041
Garments	-0.190**	(0.078)	7242	2,793	0.029
Agro-industry	-0.042	(0.123)	816	352	0.069
Food	-0.261***	(0.092)	5300	2,080	0.042
Beverages	-0.281***	(0.049)	226	105	0.208
Metals and machinery	-0.257	(0.214)	3652	1,455	0.082
Electronics	-0.063	(0.105)	3336	1,253	0.012
Chemicals and pharmaceutics	-0.294**	(0.139)	3089	1,339	0.044
Construction	-0.477	(0.831)	218	92	0.145
Wood and furniture	-0.485**	(0.217)	3603	1,454	0.056
Non-metallic & plastic mater.	-0.211*	(0.117)	2228	907	0.074
Paper	-1.206	(0.863)	481	189	0.127
Sport goods	-5.799	(3.788)	129	44	0.224
IT services	-2.164**	(0.917)	301	120	0.099
Other manufacturing	0.053	(0.412)	758	301	0.047

Note: Robust standard errors in parentheses; * significant at 10%; ** significant at 5%; *** significant at 1%. Dependent variable is value added net of labour costs over total sales value. All regressions include firms and country-year fixed effects. The coeff. column indicates the value of the energy intensity coefficient of the industry.

In our regressions, we control for country, industry and firms` characteristics effects which affect the profitability of firms in the manufacturing sector, therefore, *ceteris paribus*, the energy intensity coefficient should, at first glance, lead to higher profitability in each country and sector. Many reasons explain why the link between energy intensity and profitability is expressed by a non-significant coefficient in some countries and sectors, ***demonstrating a wide variance across firms***, even if the sign of this relationship in column 4 and 5 is negative for the majority of countries:

1) There is a mismatch between EE investments and benefits from these projects. Our data captures different levels of energy intensity, but not the timing of EE investments.

2) As shown in the IDR, different energy intensity investments provide for different payback periods and rate of returns.

3) Costs for EE are very different according to the specific technology. It is reasonable to assume that firms at an initial stage can obtain EE improvements at no cost (e.g., electricity costs savings from daily behaviours), but in the next stages, they need larger technology investments to obtain EE improvements. Hence, the impact of EE on profitability will differ in accordance with different costs.

4) Policy-driven EE interventions may require payback periods for investments that are not consistent with market conditions. As indicated in the World Development Report on climate change, to obtain a 450 ppm global atmospheric carbon concentration restriction where the incremental cost in terms of business as usual needs in developing countries would be US$ 175 billion by 2030, the investments required would amount to US$ 563 billion over and above business-as-usual investment needs. This discussion is especially relevant in countries such as China, where tight policies have been implemented to enhance EE.

Moreover, results of Section 2 of Paper 1 on the EKC existence for energy per capita reveal that for the majority of countries, it will be very unlikely that energy per capita will decrease over time without specific policy interventions (Table 4). If post-Copenhagen global agreements are reached to significantly reduce global warming and enhance EE in developing countries, policymakers will have to carefully consider the timing of the impact of massive emissions reducing technology interventions on profitability in developing countries.

5) The variables representing EE in our analysis may be biased to some extent. Cahill *et al.* (2009) points out that a definition of energy intensity based on physical units rather than on monetary values might be more appropriate to avoid distortions from price fluctuations. It could be interesting to run the same analysis with different datasets.

Moreover, as our results on the relationship between profits and EE interventions show, this varies across countries, industries and firms. Market conditions, cultural values, legal and institutional factors are only some of the examples of country-specific effects that should be considered in EE analysis. Costs and returns from EE interventions will also depend on production process characteristics and on technology, and sector-specific effects will therefore have to be included in econometric analyses linking EE and profitability. Heterogeneity of sector-specific results confirms our premise. Finally, management and internal organization issues such as the quality of the production system control, the existence of audit procedures, etc. play a role in shaping firm-specific characteristics.

Table 4 **EKC existence in the relationship between energy per capita and income per capita. Dependant variable: Energy per capita (EPC). Independent variable: Income per capita (IPC). EKC exists when in a quadratic relationship EPC = α1 + α2*IPC + α3*IPC α2 is p**

	α2	**α3**	**EKC**
Bangladesh	+ (non SIGNIFICANT)	- (non SIGNIFICANT)	NO
Benin	+ (non SIGNIFICANT)	- (non SIGNIFICANT)	NO
Brazil	+ (SIGNIFICANT)	- (SIGNIFICANT)	YES
Costa Rica	+ (SIGNIFICANT)	- (non SIGNIFICANT)	NO
Ecuador	+ (SIGNIFICANT)	- (SIGNIFICANT)	YES
Egypt	+ (non SIGNIFICANT)	- (SIGNIFICANT)	NO
El Salvador	- (non SIGNIFICANT)	+ (non SIGNIFICANT)	NO
Ethiopia	- (SIGNIFICANT)	+ (non SIGNIFICANT)	NO
Guatemala	+ (SIGNIFICANT)	- (SIGNIFICANT)	YES
Guyana	+ (SIGNIFICANT)	- (SIGNIFICANT)	YES
Honduras	- (non SIGNIFICANT)	+ (non SIGNIFICANT)	NO
India	+ (non SIGNIFICANT)	+ (non SIGNIFICANT)	NO
Indonesia	+ (non SIGNIFICANT)	- (non SIGNIFICANT)	NO
Madagascar	+ (non SIGNIFICANT)	+ (SIGNIFICANT)	NO
Malawi	+ (SIGNIFICANT)	- (SIGNIFICANT)	YES
Mauritius	- (non SIGNIFICANT)	+ (SIGNIFICANT)	NO
Nicaragua	+ (SIGNIFICANT)	- (SIGNIFICANT)	YES
Pakistan	+ (SIGNIFICANT)	- (SIGNIFICANT)	YES
Peru	+ (SIGNIFICANT)	- (SIGNIFICANT)	YES
South Africa	+ (SIGNIFICANT)	- (SIGNIFICANT)	YES
Sri Lanka	+ (non SIGNIFICANT)	- (SIGNIFICANT)	NO
Tanzania	+ (non SIGNIFICANT)	- (non SIGNIFICANT)	NO
Thailand	+ (SIGNIFICANT)	- (non SIGNIFICANT)	NO
Viet Nam	+ (SIGNIFICANT)	- (SIGNIFICANT)	YES

2. Does energy efficiency lead to innovation in the use of other inputs?

Economists generally express EE as an increase in the energy marginal productivity curve. Given a typical Cobb Douglas function:

1) $Y = AK^{\alpha} L^{\beta} E^{\gamma}$

Where Y is output, L is labour, E is energy and K is capital, A represents technological change increasing value added. In other words the level of output will depend on the inputs (K, L, E), on the marginal productivity of each input (α, β, γ) and on the parameter A (multifactor productivity) governing long-run growth rates and the value added increase associated with each capital – labour – energy technology through a proportional rule. EE is represented by an increase of the γ parameter. Holding the level of K and L constant, an increase of the γ parameter means that the same output level can be obtained by a lower level of energy.

Another important question is whether EE can lead to an increase in total factor productivity and, in particular, to the productivity of other inputs beyond energy. In other words, from a business perspective, it is interesting to analyse whether EE stimulates a more value added use of other inputs like capital and labour. In a recent study, Cadot et al. (2009) investigate this issue by considering a production function including capital and labour:

2) $Y = AK^{\alpha} L^{\beta}$

Through this production function, they estimate the value of multifactor productivity (MFP) A and in a next stage, test whether in a sample of firms of six developed countries, EE is positively correlated to multifactor productivity (MFP = f(EE)). Specifically, they test Porter and van der Linde`s (1995) hypothesis claiming that firms which are forced to increase EE because of higher energy prices adapt to these new conditions by investing in innovation processes based on the use of other inputs. Their econometric analysis confirms Porter and van der Linde’s assumption. The EE variable in their study is represented by energy price, as they implicitly assume that higher energy prices generate energy savings.

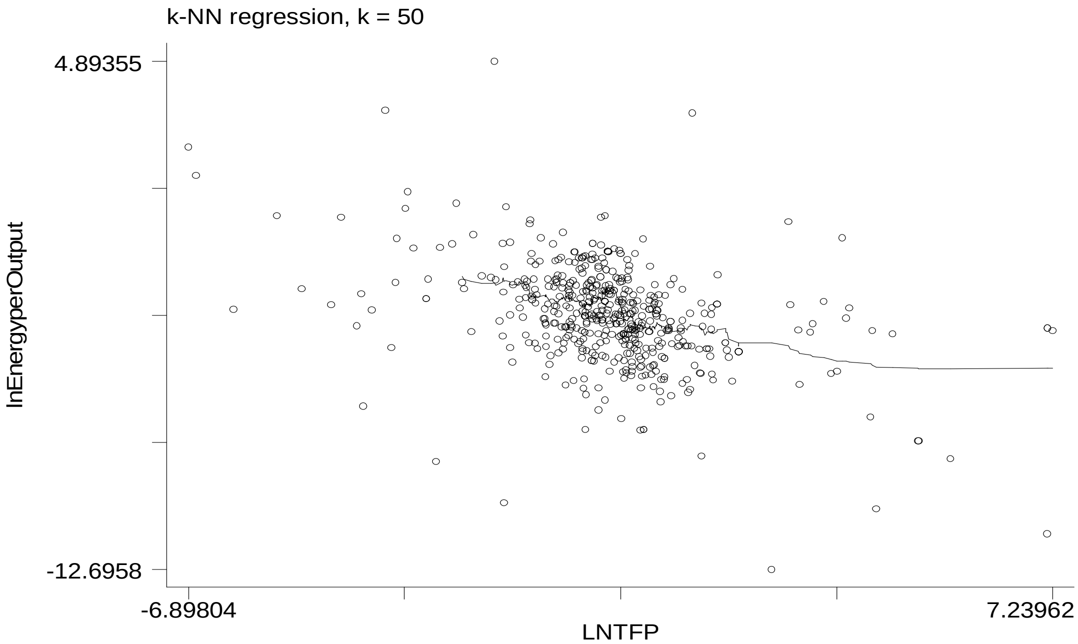
Our regression analysis contained in **Paper 1** follows a very similar approach. Using the World Bank Enterprise Survey data, we estimate Equation 1 to calculate MFP. In a second step, we implement a regression analysis where EE can be explained by a set of variables including MFP. The difference to the Cadot et al. model is relevant because we estimate EE = f(MFP). A second relevant difference to the Cadot et al approach is that we do not specifically test Porter and van der Linde`s hypothesis as we are interested in verifying the relationship between MFP and EE under more general market conditions rather than under policy stimuli alone. Finally, we carry out a regression analysis where EE depends on other relevant factors such as firm characteristics and barriers to the adoption of innovation, such as telecommunication, credit constraints, etc.

An interesting conclusion of our paper is that for 23 out of 24 countries, there is a strong and negative relationship between energy intensity levels and multifactor productivity. The most innovative firms are those with the lowest level of energy intensity. However, as we specify in our Paper 1: "We do not have enough evidence to show that the causal relationship goes from technological change to EE or rather the other way around (or both)".

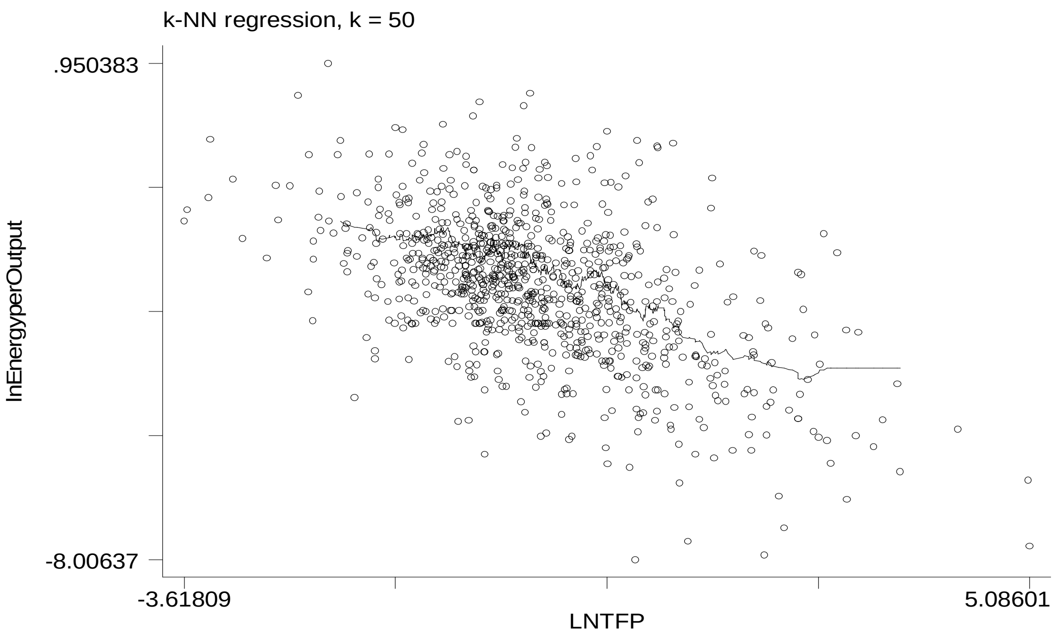
In other words, Cadot et al. show that EE induced by price shocks affects multifactor productivity and ***our results contained in Paper 1*** show that multifactor productivity affects energy intensity levels. Econometric studies including Granger causality tests could be very useful to complete the discussion, but at this stage, at least from an economic intuition, we have good reasons to believe that EE and multifactor productivity influence each other. On the one hand, a higher level of multifactor productivity generates high income over time and resources that can be used for innovation investments. On the other hand, EE technology improvements can create the management, know-how and procedural conditions to speed up the innovation process based on the use of other inputs. Further research is needed to analyse this relationship in depth, but at this stage it is important to emphasize that our results show the existence of a strict correlation between these two crucial variables.

Figure 1 Non-parametric estimation of multifactor productivity (ln) vs energy intensity (ln)

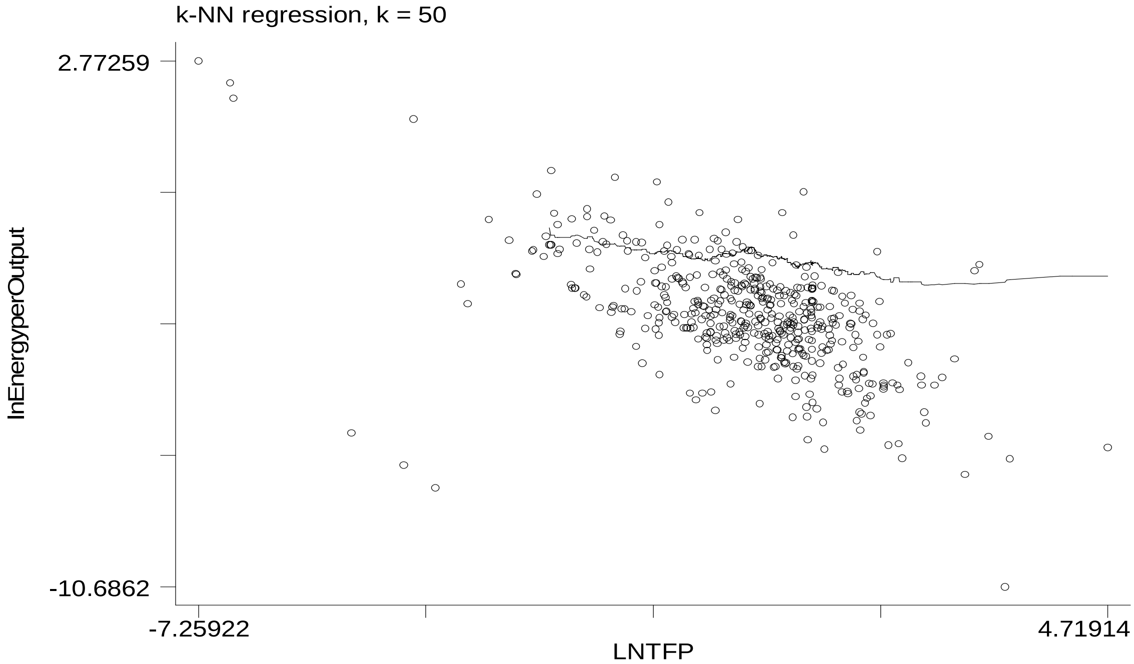
Indonesia



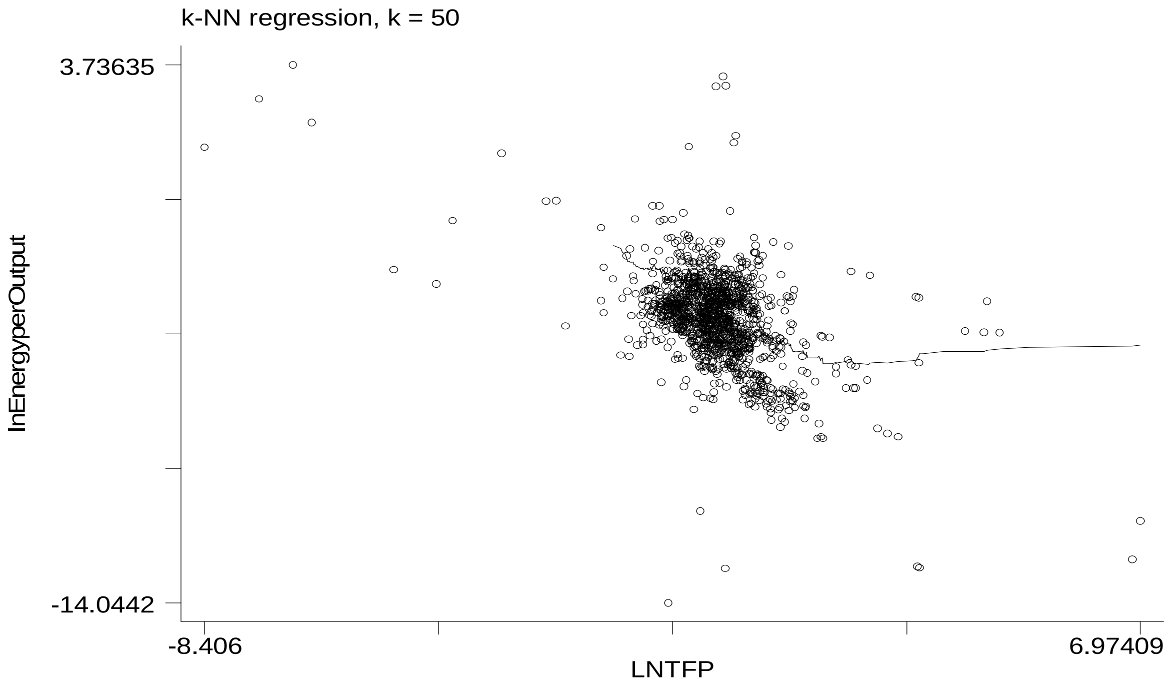
Pakistan



Ethiopia



South Africa



3. Barriers to the adoption of energy efficiency

As we have seen in the previous paragraphs, EE is good for the environment as lower levels of energy consumption generate lower emissions and may be good for economic performance, as EE technology adoption generally provides benefits, boosts profits at the "micro" level and economic growth at the macro level.

An important research endeavour is, therefore, to identify the constraints that prevent firms from implementing win–win EE technology interventions to correct possible market failures. To identify these, discrete choice models are used as an appropriate investigation tool. The idea is to consider a categorical dependant variable (YES technology adoption = 1, NO technology adoption = 0) and investigate the determinants of EE technology adoption for different sectors and contexts. Schleich and Grueber (2008) and Schleich (2009) already carried out two interesting discrete choice analyses on EE adoption for different sectors of Germany, however, a full analysis of developing countries is still missing. UNIDO has recently collected data on EE adoption in many developing countries. ODI develops a discrete choice analysis in **Paper 4** to investigate the relevance of different business constraints in reducing the likelihood of adoption in Viet Nam, Moldova, Thailand and Philippines. The choice of regressors is based on a UNIDO paper (2007) that specifies policies that seem most promising to boost EE adoption and on data availability. Paper 4 describes three different steps:

In the first step, data on eight business constraints are assessed using principal component analysis (PCA). Respondents in developing countries were asked to evaluate the severity of different business constraints on a scale (1 = poor relevance – 4 = high relevance). The objective of this section is to reduce the number of business constraint variables to a lower number of independent variables. The eight business constraints are summarized in Table 1. ***Interestingly, we extract the information respondents perceive homogenously from the PCA, namely the relevance of micro and macroeconomic business constraints***. Our interpretation of this finding is that respondents tend to consider internal and external constraints as distinct features that should be treated with different tools and resources. Whereas in Component 1 higher loading scores are associated with variables representing macroeconomic conditions (policy, market, information circulation), Component 2 is associated with microeconomic factors (top management, lack of capital, risk of production interruption).

Table 5 Principal component analysis applied to data on respondents` assessments of the relevance of business constraints

Variables	Component 1	Component 2
Top management commitment	.358	**.446**
Lack of expertise of energy efficiency projects	.607	.127
Production interruption	.059	**.830**
Lack of capital	.134	**.668**
Insufficient information on costs and benefits of energy efficiency	**.702**	.153
The market does not place any value added to energy efficiency	**.755**	-.019
Existing policies are inadequate to promote and support energy efficiency	**.789**	.279
Lack of external drivers such as mandatory CO2 emissions targets	.698	.305

In the second step we use the two "micro" and "macro" PCA components as regressors in a discrete choice analysis where the dependant variable is Technology adoption = YES, Technology adoption = NO and other regressors are represented by other firm characteristics related to the business firms` characteristics and environment (country, number of workers) or that are strictly related to the firms' energy management.

Interestingly, our finding is that variables related to the firm management's approach to energy have a significant impact on EE. The presence of energy audits and the intention to plan or consider energy management innovation show a positive and significant sign expressing the increase in the likelihood of EE adoption**.** ***Microeconomic business constraints (the variable Component 2 – microeconomic constraints) reduce the likelihood propensity to invest in new technology whereas macroeconomic business constraints (Component 2) are not relevant.***

Finally, firms adopting a management system standard are less likely to invest in EE. This result could be explained by the fact that firms` choice to adopt a certification system may offset further investments in energy efficiency. Firms` management may feel that the accomplishment of the standards is already an appropriate means to reach an efficient production process and reduce the innovation process.

Though management certification may represent a stimulus for developing countries to improve business competitiveness, results would suggest promoting those management and international organization changes that can guarantee a dynamic path of innovation rather than the static accomplishment of standards for EE improvements.

The rationale behind these results is that firms seem to be oriented towards EE technology adoption when interventions are profitable and with the presence of internal energy management experts, systems and procedural structures that can easily promote this transition towards EE. Based on our results it is clear that external inputs deriving from market or policy may be useless if they address firms which are not suitable for driving the transition towards energy technology innovation.

Another interesting result is that firms which have already invested in EE are more likely to invest in the next years (with a 0.10 significance level). In other words, we find a path dependency of firms' behaviour in terms of investments in EE.

Rather than focussing on generic macroeconomic policies, international organizations seeking to promote EE should adopt measures aimed at changing the international organization of firms and at encouraging investments in technology, especially for those firms which have not yet made such investments in the past. Our results indicate that learning by doing aspects play a role in investment choices. International organizations such as UNIDO will be crucial to provide technical assistance through local projects to encourage the commencement of energy efficiency innovations in developing countries.

Table 6 Results of the logit model. Dependant variable: is your company considering or planning to invest in energy efficiency projects in the next five years? (odds ratio YES/NOT). 116 observations.

Variable	B	SE	df	Sig.	Exp(b)
Constant	.159	1.459	1	.913	1.172
Energy audit (YES)	2.705	1.119	1	.016	14.951
Staff awareness programmes (YES)	-.311	1.358	1	.819	.732
Existence of energy policy (YES)	-.886	.988	1	.369	.412
Existence of energy performance indicators (YES)	-.447	.841	1	.595	.640
Country: Philippines	1.141	.991	1	.249	3.131
Country: Moldova	-.331	1.647	1	.841	.718
Planning or considering energy management innovation (YES)	1.909	.902	1	.034	6.747
Energy reduction targets (YES)	.762	1.060	1	.472	2.142
Certification (YES)	-2.371	1.199	1	.048	.093
Investments in energy efficiency in the last two years (YES)	1.593	.949	1	.093	4.917
Component 1: external conditions	-.253	.436	1	.561	.776
Component 2: microeconomic constraints	-1.133	.458	1	.013	.322
Number of employees	.001	.001	1	.185	1.001

In the third step, we run the same regression as in Table 6 by replacing Component 1 and Component 2 derived from our PCA analysis with specific business constraints. We run the same regression analysis as in Table 6 by including the entire set of eight business constraints. We adopt a Likelihood Ratio and Wald tests forward selection procedures to identify the most meaningful variables and barriers affecting plans to adopt EE technology. ***As is evident in Table 7, we confirm that microeconomic conditions affect the likelihood to invest in EE.*** With this revised model specification we confirm that propensity to energy management innovation and past experience in EE technology investments increase the likelihood that a firm in developing countries plans to introduce new technology. ***Interestingly, we also find that among the barriers, top management commitment is very relevant. In other words, the more firms***

perceive top management's commitment as a business constraint, the less is the likelihood to invest in EE.

Table 7 Results of the logit model. Dependant variable: is your company considering or planning to invest in energy efficiency projects in the next five years? (odds ratio YES/NOT). 116 observations. LR and Wald test forward variable selection procedures

Variable	B	SE	df	Sig.	Exp(b)
Constant	1.434	1.165	1	.000	16.169
Investments in energy efficiency in the last two years (YES)	1.656	.711	1	.020	5.237
Planning or considering energy management innovation (YES)	1.978	.799	1	.013	7.227
Top management commitment is a poor relevant business constraint*	-3.532	1.158	1	.002	.029
Top management commitment is a relevant business constraint	-2.921	1.271	1	.022	.054
Top management commitment is a very relevant business constraint	-2.371	1.525	1	.120	.093

** We drop the dummy variable "Top management commitment is **a very poorly relevant** business constraint". The coefficients associated to the variables "Top management – **poorly relevant, relevant, very relevant**" represent the increase (+) or the decrease (-) of likelihood to invest in EE if compared to firms where the top management commitment is a very poorly relevant business constraint.*

Finally, we point out that the previous regression results on the factors determining EE adoption appear to be homogenous across countries. This result may derive from the fact that our results are obtained from 116 observations only, which may not be sufficient to capture the heterogeneity of barriers. If we consider the results of ***Paper 1*** in which we investigate the impact of multifactor productivity, capital per capita and two business constraints (credit constraints and telecommunication) at the firms` level of energy intensity in developing countries, they appear to be much more heterogeneous when using a wider dataset.

The effects of business constraints variables are mixed. Whereas for India and Guatemala, telecommunications business barriers (variable hightelecom) increase energy consumption, the opposite effect is found in Egypt and Viet Nam. This contradiction could be explained by different measures firms could adopt to tackle market failures. On the one hand, barriers to communication flow may represent an obstacle to innovation and limit the adoption of energy saving technologies. On the other hand, high telecommunications barriers may induce firms to stimulate business by pursuing cost savings and EE that they can control with more effectiveness rather than infrastructural facilities. Similar results are found for credit access business barriers (variable highconscredit).

Table 8 Energy efficiency and productivity. Dependant variable: Energy intensity

	(EGY)	**(GTM)**	**(IND)**	**(VNM)**
Log of capital per worker [ln(K/L)]	-.144***	-.123**	-.070**	-.077**
Ln(TFP)	-.588***	-.686***	-.508***	-.590***
Constant	-3.343***	-3.075***	-3.727***	-3.184***
hightelecom	-0.994**	.470***	.301***	-.256**
highconscredit	.054	.038	-.042	.109*
ISO	-0.274	-.028		-.217***
age	-.000	-.001	.003*	.004**
comp		.000		
skillsworkers	-.001		-.003**	-.011***
foreign ownership	-.026	-.348*	-.058	-.475***
Industry dummy variables	yes	yes	yes	yes
Year	2004	2001-2003	2000-2002	2003-2005
Observations	488	710	2558	2380
R square	0.261	0.266	0.198	0.199

Notes: The dependent variable is the log of energy consumption per sales; output is defined as total sales; industry dummy variables; *, ** and *** indicate significance at 10, 5 and 1 percent, respectively. Robust standard errors.

4. Conclusions

ODI developed a series of papers covering many hot topics about the current discussion in EE and in particular:

1) The link between EE, profitability and technical progress;
2) The macroeconomic path of EE and economic structural change in different developing countries;
3) The identification of EE technology adoption;

4) The existence of a turning point in the relationship between income per capita and energy consumption per capita for firms in developing countries.

Our analysis and previous literature shows that EE may induce profit increases and innovation in developing countries. Our analysis on the link between EE and profitability shows that investment projects in EE have different payback periods, returns and costs, and this heterogeneity may explain why we find a significant and negative coefficient linking energy intensity levels to profitability in many, but not in all countries. However, when we investigate the link between energy intensity and total factor productivity, we find a strong and negative relationship for almost all countries. The most dynamic firms in implementing EE technology are also the most innovative from an economic point of view in combining efficiency inputs. However, the extent to which innovation is translated into profit rate increases for firms varies across countries, sectors, typology of investments, etc.

Policy will have to help remove all the barriers and market failures that reduce the adoption of EE technologies which produce win–win benefits for the environment and economy. In particular, decision-makers will have to focus on all aspects related to microeconomic, management and internal organization of firms. Our EKC analysis (**Paper 1**) shows that energy per capita does not follow a decreasing path in the majority of developing countries and **Paper 3** reveals that the majority of countries are experiencing a structural change towards dirty sectors in the growth path. If policymakers decide to impose the adoption of the EE lever to combat global warming, they will need to seriously consider that firms will have to bear a mismatch between a massive amount of required investments in frontier technology and the time lag for the enjoyment of benefits. Environment policy will likely require strong investments for deep emissions cuts and firms in developing countries may not be solid enough to absorb long payback periods for EE investments. Appropriate financing mechanisms will have to be put in place to encourage transition towards a green economy in developing countries.

In the meantime, in a context where global climate change agreements are still far from being reached, policymakers pursing both environmental and growth targets will have to remove the barriers which currently reduce the propensity of firms to invest in profitable EE projects. A priority at this stage should be to encourage firms to invest in all those projects providing rapid and huge rewards with the aim to promote both the environment and development.

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II. Promoting energy efficiency in developing countries – new evidence based on firm analysis Phase 1

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Abstract

This paper uses an econometric analysis on the basis of firm-level data in 24 developing countries to examine the determinants of energy efficiency in developing countries. We find robust evidence that productivity (which can be interpreted as technological change) and energy efficiency are strongly correlated. This result is confirmed by evidence in many developing countries of the existence of the Environmental Kuznetz Curve hypothesis when we consider the relationship between energy intensity and output at the firm level. Moreover, the sectoral distribution in the national economy matters for determining energy efficiency, as different sectors have different energy intensities and different correlations with productivity. Finally, we find that a set of firm characteristics and business constraints affect energy intensity and the sign of their impact is not clear.

From a policy perspective, two insights emerge. First, evidence supports the claim that normal development policies aimed at improving productivity could be win-win as they go hand in hand with improvements in energy intensity. However, it may also be that targeting energy efficiency can be helpful but that only more in-depth research will help us determine cause and effect. Second, the country-specific results point at the need to implement policies that consider the specific economic and social situations in each country.

Our analysis suggests the need for further research to understand the energy intensity determinants. The research could be extended at both micro and macro levels. At micro level, it will be important to examine in depth the factors that condition the adoption of environmental friendly and cost saving technologies in each firm. The analysis on the basis of the World Bank Enterprise Survey Data cannot be used to satisfactorily answer all questions concerning the barriers to innovation and factors determining energy intensity. Direct interviews with local experts in developing countries are very useful to fill the gap. Interviews are also useful to

analyse the endogeneity issue of the relationship between energy efficiency and productivity in depth.

Moreover, our analysis shows the need for a complementary analysis which focuses on macroeconomic issues. Our results suggest that the structural composition in developing countries matters for energy intensity and a macroeconomic analysis run by macro sectoral data could shed light on the path of energy intensity in each country. The shift share technique (Esteban 2000) is a very useful tool to study the dynamics of energy intensity of each country over time (for those countries with data). This is a technique that allows the verification whether discrepancies among regions in terms of energy intensity depend on their structural composition (low energy intensive vs high energy intensive economies) or from inefficiencies (high energy demanding vs low energy demanding countries). Finally, from a macroeconomic perspective it would be interesting to investigate the EKC hypothesis for a selection of developing countries.

1. Introduction

Demand for energy worldwide is rising at a fast rate. The IEA's 2008 World Energy Outlook reference scenario estimates world primary energy demand to grow by 1.6 percent per year on average between 2006 and 2030 for an overall increase of 45 percent. The majority of this growth will be in developing countries, 87 percent of the projected increase in demand will take place in non-OECD countries, 50 percent of total demand will come from China and India alone (IEA, 2008). We therefore need to understand what can reduce energy demand and specifically, what can be done to promote energy efficiency while safeguarding productivity and incomes.

The McKinsey Global Institute finds that 65 percent of all available positive return opportunities for investment in energy efficiency are located in developing regions (Farrell and Remes, 2009). An estimated investment of US$ 90 billion in the next twelve years could save these developing countries $600 billion annually by 2020 in energy savings. This investment of $90 billion is projected to be only half of the required investment to keep up with energy demand growth without improved efficiency measures. Industrial efficiency improvements to produce more economic output with less energy input is essential for reasons of energy supply security, economic competitiveness through improved industry profitability, improvement in livelihoods, and environmental sustainability (Taylor et al, 2008).

This paper examines the link between energy efficiency and productivity at the firm level. We will first use firm-level data for a number of developing countries, presenting data on energy efficiency across different manufacturing sectors in different countries, and explain energy efficiency by a number of firm-level characteristics, including productivity and other factors determining the uptake of green technology. We use a panel of 24 developing countries.

Second, we will set this analysis in the literature on why energy efficiency techniques are not always adopted even though they seem productive and try to derive country specific implications for institutions and policies that can help to overcome the market and coordination failures associated with the adoption of green technologies.

We will then make suggestions for phase 2 research on what is holding back investment in energy efficiency and to discuss the link between energy efficiency and productivity in developing countries.

The structure of this paper is as follows. Section 2 contains a selected literature review on energy efficiency. Section 3 explains data and methodology issues, Section 4 describes the results, and the final section concludes and provides some suggestions for the next research phase.

2. Background

This section discusses the definition of energy efficiency (2.1), the benefits of energy efficiency (2.2) and introduces an overview of the main research questions addressed in this paper.

2.1 Defining energy efficiency

Though there are several definitions of energy efficiency measures, “energy intensity measures are often used to measure energy efficiency and its change over time [….] [E]nergy-intensity measures are at best a rough surrogate for energy efficiency. This is because energy intensity may mask structural and behavioural changes that do not represent “true” efficiency improvements” (EIA, 2003). Energy intensity is simply a ratio of energy input to industrial output; an economic-thermodynamic type of efficiency measure. “In comparison to the application of thermal efficiency measurement, indices of energy consumption can be used to assess and compare energy performance for a broader set of objects: processes, factories, companies, and even countries” (Tanaka, 2008). Most studies use a measure of energy intensity, or energy productivity, which is the inverse.

Industrial output may be measured by some sort of common physical unit at lower levels of aggregation, but will necessarily be measured in economic value taking account of purchasing power parity at economic or national levels of aggregation. It is well noted in the literature that even at the 2-digit SIC level of industrial classification, common physical output measures are not possible. There are a number of ways to measure output of industry but "it seems that value of production is the most desirable value-based output measure for use in an indicator of energy intensity" (Freeman et al. 1997). Differences between intensity measures using volume and those using value-based output may entail measurement errors in price indexes, errors in industry specialization and coverage or industry redefinitions (Freeman et al. 1997).

2.2 Understanding the benefits of energy efficiency

Recent research contributions (summarized in Table 1) focus on the benefits derived from energy efficiency, especially from a macroeconomic perspective. Many empirical studies agree that energy efficiency generates positive economic outcomes such as higher output, competitiveness (Taylor et al. 2008) and employment (IEA 2009), as well as environmental improvements induced by lower energy bills (WEC 2008) and sustainable production methods (World Bank 2006). Although energy efficiency, as part of the technical progress in neo-classical growth theory, is conventionally seen as a driver of economic growth, there is evidence that this is not always true (Madlener & Alcott 2009). Akinlo (2008) finds that the existence and direction of causality between energy consumption and economic growth is not homogenous across sub-Saharan Africa.

Even from a theoretical perspective, the issue concerning the impact of energy efficiency is still controversial. Wei (2007) theorizes short-term and long-term effects of increased energy efficiency and, in the short term, a 100 percent rebound effect is found such that energy efficiency gains have no effect on absolute energy use. In the long term, the impact on non-energy output of energy end-use efficiency is positive. Van Zon and Yetkiner (2003) adapt the Romer model to "include energy consumption of intermediates and to make intermediates become heterogeneous due to endogenous energy-saving technical change." They find that economic growth rate positively depends on the rate of embodied energy-saving technical change.

Reports and studies of different research and international organizations describe macroeconomic indicators of energy efficiency in different sectors and countries. They suggest a decreasing path of energy intensity over time, but results widely differ among countries.

Whereas in Europe, North America and China we can identify a negative trend, in Africa, Latin America, India and the Middle East we do not find an unambiguous decreasing path. Moreover, it is not clear if there is a positive (or negative) relationship between the levels of energy intensity and GDP (see Annex I). This implies that from a policy point of view, we cannot safely claim that growth enhances efficiency in energy use over time.

Table 9 Empirical benefits of increased industrial energy use efficiency

Benefit	Source	Comments
More economic output without requiring additional, possibly constrained, energy supply – firm and national level benefit	Taylor et al (2008), Semboya (1994), UNDP (2006), McKane et al (2007),	This is particularly important in regions where electricity and energy supply are constrained, such as in many African and Asian countries. Not only will greater output be feasible without increasing energy demand, but less investment will be necessary in energy production capacity (WEC 2008:9).
Lower production/energy costs – at the firm level	UNDP-Kenya (2006), Farrell and Remes (2009), Semboya (1994), WEC (2008), McKane et al (2007),	"Costs vary among technologies and countries where energy efficiency measures are implemented, but often are only one-quarter to one-half the comparable costs of acquiring additional energy supply" (Taylor et al 2008:27).
Economic competitiveness (through lower prices) – national and firm-level benefit	Taylor et al (2008), UNDP-Kenya (2006), Semboya (1994), WEC (2008),	At the firm level, higher efficiency will improve competitiveness through lower costs.
Creates jobs (indirectly) *	UNDP-Kenya (2006), IEA (2009),	By increasing the use of high-tech efficient machinery, high-skill technicians will be more in demand. Also, by improving competitiveness, the firm will presumably grow and be able to employ more workers.
Improvement in livelihoods/ reduce poverty*	Taylor et al (2008), UNDP-Kenya (2006), WEC (2008),	Poverty is reduced by an increase in jobs.
Energy supply/price security and reduced uncertainty*	Taylor et al (2008), UNDP-Kenya (2006), World Bank (2006), IEA (2009), WEC (2008), McKane et al (2007), Farrell and Remes (2009),	Particularly for oil importing countries (WEC 2008:105).
Environmental sustainability	Taylor et al (2008), World Bank (2006), IEA (2009), UNDP (2006), WEC (2008) –extends availability of fossil resources,	"Energy efficiency is favored in environmental improvement strategies because it reduces the need for energy development, transportation and distribution, onsite use, and all the associated environmental impacts" (Taylor et al 2008:27)
Reduce import bill (nationally)	UNDP-Kenya (2006), Semboya (1994); and improve balance of trade: UNDP-Kenya (2006), Semboya (1994), WEC (2008),	"[E]nergy imports are replaced (in many countries) by domestically produced energy-efficient products and (energy) services" (UNDP 2000:185). Greater industrial outputs can increase exports.

Whilst we have identified an extensive literature (although there is no consensus on most issues), studies on microeconomic aspects of energy efficiency still represent a narrow field of research that is often limited to individual countries (de Groot et al. 2001 for The Netherlands and Kumar 2003 for India). In this paper, we will fill this gap by investigating energy efficiency for a large set of developing countries at the firm level. Researchers and policymakers have hypothesized that rules and institutions that promote investment in energy efficiency also help productivity enhancements essential for promoting development and reducing poverty (see, for example, Porter and van der Linde, 1995). They argue that energy efficiency improvements provide a means to reduce costs without adversely affecting output or eroding a firm's competitive edge. In addition, energy efficiency is also considered to reduce the unpredictability of earnings associated with the current volatility of energy prices in the present day world economy.

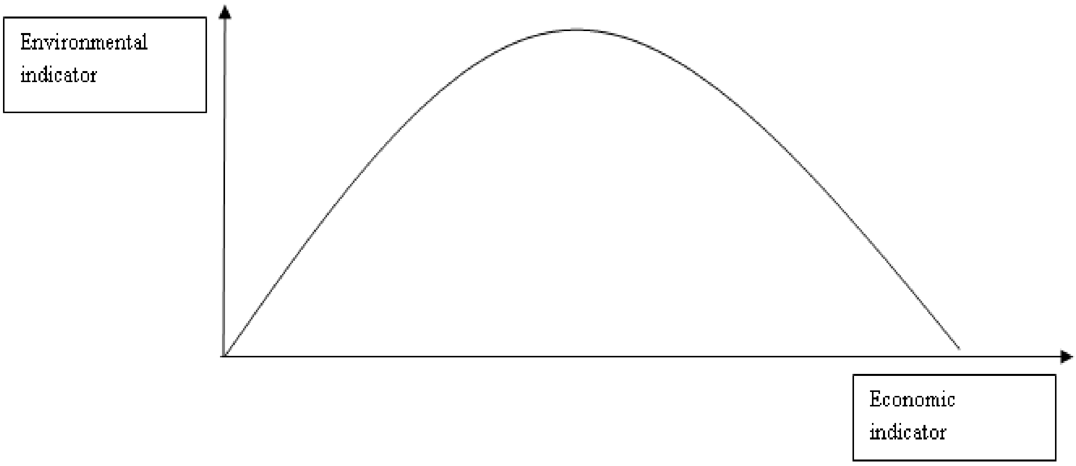
2.3 New research questions

The first hypothesis that we examine here is that investing in technical change may automatically lead to greater energy efficiency if this incorporates the latest, more energy efficient techniques (Inhaber 1997; Huber and Mills 2005). This trend is referred to as the 'autonomous energy efficiency improvement technological change'. For example, Hogan and Jorgenson (1991) estimate that technological change alone caused a reduction in US energy intensity by about 0.3 percent per year, independent of changes in energy prices or standards. Koopmans and Te Velde (2001) find that energy efficiency improved by 1.1 percent a year in the Netherlands. There is, however, very limited evidence available for developing countries on the link between energy efficiency and technical change, although the issue is becoming increasingly important for them. Many large developing countries, especially in Asia, have experienced buoyant economic growth in recent years and their energy use has soared tremendously.

Grossman and Krueger (1991) summarize the different channels through which economic growth affects the environment into three categories: the scale, composition and technique effects. The scale effect represents the effect of economic growth on the environment through the expansion of production activities. The composition effect refers to the environmental consequences of structural changes in the economy induced by economic growth. Finally, the technique effect reflects the movement away from environmentally hazardous production methods to cleaner ones as a result of the technological progress accompanying economic growth. It involves changes in the state of technology, which enhance production efficiency, as well as changes in consumers' preferences for better environmental quality with rising incomes. In this paper we are concerned with the *technique* effect.

The scale, composition and technique effects are the so called "decomposition effects" related to the well-known concept of the environmental Kuznets Curve (EKC). The EKC hypothesis implies that if a bell shaped relationship between economic activity levels and pollution exists, and if we can identify a turning point in the pollution-income relationship (see Figure 1), the best way to tackle environmental issues is to foster growth.

Figure 2 The Environmental Kuznets curve hypothesis



Extensive literature has been published which examines the EKC hypothesis for many pollutants at national and global level, but evidence at macro level is fragile, especially for global pollutants (Galeotti et al. 2006; Cantore 2009). The literature that specifically deals with the existence of the EKC for the specific issue of energy intensity is still narrow (Howart et al. 1991; Mazzanti and Zoboli 2006) and only few attempts have been made to deal with the EKC curve at the micro level. The EKC existence for energy efficiency in a set of low income countries is the second relevant hypothesis we will investigate.

Finally, the third and policy relevant issue we are examining in this paper is the identification of factors representing barriers to technological change to enhance energy efficiency. An interesting strand of the literature identifies critical factors which influence the adoption of new and efficient technologies (see Table 2). Barriers to knowledge flow (Meyers 1998), credit access (Farrell and Reme 2009) and technology (Mc Kane et al. 2007), the uncertainty in the future projection of oil prices (Koopmans and Te Velde; 2001), erroneous national policy choices (Reddy 1991) and previous firm investment decisions (UNDP 2006) could represent severe obstacles to the adoption of innovative technologies for energy saving. Moreover, other factors such as the "age" of firms (Cainelli et al. 2007), firms' governance designs (Quereshi and Te Velde 2006), the size of the firms' economic activity and sector-specific features (Cainelli et al. 2006) could play a role in affecting the level of energy intensity over time.

The World Bank sponsored three Country Energy Efficiency Programmes which aimed to finance energy efficiency in Brazil, China and India. In these countries, the World Bank finds that "the core of the problem […] lies in the intertwined problems of perceived high risk driving up implicit discount rates associated with projects, currently high transaction costs, and difficulties in structuring workable contracts for preparing, financing, and implementing energy efficiency investments" (Taylor, et al 2008). The report stresses that the barriers are institutional issues: "two core economic functions that are dependent upon the strength of prevailing market institutions are usually critical for efficient energy efficiency investment: (i) outsourcing governed by contracts to allow sufficient specialization, and (ii) deep and efficient financial markets for financing energy-efficient investments (including both initial and retrofit investments)" (Taylor et al 2008:51-52).This finding is consistent with a recent report provided by SBSTA (2006) analysing factors affecting the transfer of environmental friendly technology in developing countries. The document reviews the Technology Needs Assessments submitted by 23 developing countries to UNFCC and outlines the factors that are indicated as being crucial for the diffusion of clean technologies. 65 percent of countries indicate institutional factors as being crucial together with market, policy, human capacity and technical elements as specified in Table 2.

Table 10 % representing the share (in a sample of 23 countries) of developing countries that identify a technological transfer barrier as being crucial in the Technology Needs Assessment document submitted to the UNFCC (United Nations Framework Convention)

Economic and market barriers	83%
Policy barriers	78%
Technical barriers	74%
Human capacity	70%
Institutional barriers	65%

Source: SBSTA (2006)

In this paper, we directly address these issues by providing new empirical evidence using micro-level data concerning the causes that prevent firms from investing in efficient technologies.

Table 11 Barriers to investment in efficient technologies in relevant industries in developing countries

Informational Barriers	Lack of knowledge of technology availability & benefits	Reddy 1991; UNDP 2000; McKane 2007; Farrell and Reme 2009; Taylor et al 2008; Preaetorius & Bleyl 2006; WEC 2008;
	Institutional barriers to knowledge, communication and technology flows	Meyers 1998;
Financial Barriers	Lack of available funds/ absence of credit	Reddy 1991; Farrell and Reme 2009; Taylor et al 2008; Meyers 1998; WEC 2008;
	First-price sensitivity/high capital costs (magnified by the lack of credit markets)	UNDP 2000; Reddy 1991; Behrens et al 2009; Meyers 1998; WEC 2008;
Technological barriers	Unavailability of efficient equipment (technology available but not produced)	Reddy 1991; Meyers 1998;
	Focus on individual component efficiency, not whole system efficiency	McKane et al 2007;
	Misapplication of efficient technologies	McKane et al 2007;
	Shortage of trained technical personnel to maintain/install new equipment	Reddy 1991; McKane et al 2007; Taylor et al 2008; UNDP 2000;
Discrepancies in discount rate	Uncertainty about future energy prices/economic uncertainty	Reddy 1991; McKane et al 2007; Taylor et al 2008;
	High user discount rates	Taylor et al 2008; Behrens et al 2009; Meyers 1998;
	Slow rate of capital turnover/ infrequency of capital investments	McKane et al 2007;
	Perceived risk of implementing the new/unfamiliar technology	McKane et al 2007; Taylor et al 2008; Meyers 1998; IEA 2009;
	Indifference to energy costs/relative insignificance of energy costs to total costs	Reddy 1991; Meyers 1998;
	Below long-run marginal cost pricing and other price distortions	Taylor et al 2008; Meyers 1998; IEA 2009;
	High transaction costs	Behrens et al 2009; Taylor et al 2008; Meyers 1998;
Diversity of investment criteria and limited resources	Inherited inefficient equipment/indirect purchase decisions	Reddy 1991; UNDP 2000; Meyers 1998; WEC 2008;
	Limited fuel options/supply	UNDP 2000;
	Historically or socially formed investment patterns	UNDP 2000; McKane et al. 2007;
	Mismatch of the incidence of investment costs and energy savings	Taylor et al 2008;
	Import of inefficiently used plants and vehicles	UNDP 2000; Meyers 1998;
Policy/political barriers	Political uncertainty/ policy instability	Taylor et al 2008;
	Weak contracting institutions	Taylor et al 2008; Meyers 1998;
	Absence of effective energy efficiency policy at national level	Reddy 1991; UNDP 2000; Behrens et al 2009; Taylor et al 2008;
	Inappropriate energy pricing and cross-subsidizing	UNDP 2000; Farrell and Reme 2009; Meyers 1998;
	Skills-short government	Reddy 1991; Meyers 1998;
	Government without adequate training facilities	Reddy 1991;
	Government without access to necessary hardware and software	Reddy 1991;

3. Data and methodology

To assess the link between energy efficiency and productivity, we follow Te Velde (2008) to estimate the following equation:

$$\ln\left(\frac{E}{Y}\right)_{it} = \alpha_1 + \alpha_2 \ln\left(\frac{K}{L}\right)_{it} + \alpha_3 \ln TFP_{it} + X_{it}\beta_1 + Z_{it}\beta_2 + \lambda + u_{it} \qquad (1)$$

where i = 1,.., n stands for firm i and t denotes time, E is total energy consumption, Y is output, L is labour, K is physical capital, and TFP is total factor productivity estimated using a Cobb-Douglas production function, β is a column vector of k parameters $\beta_{1,2} = (\beta_1, \ldots \beta_K)'$, X_{it} is a row vector of k variables which includes firm characteristics (age, foreign ownership, ISO9000 certification, number of competitors and percentage of permanent workers with at least 12 years of education) and Z is a vector of factors representing barriers to technological innovation (telecommunication and credit access barriers). λ denotes dummy variables representing the economic sector where the firm is active (see Annex III for a full list describing the disaggregation of economic sectors and Appendix IX for a more accurate description of the variables). X and Z variables are not expressed as logarithms, therefore, coefficients should be interpreted as semi elasticity for continuous explanatory variables and as usual regression lines shift components for dummy variables. Coefficients associated to capital per worker and TFP are elasticities.

The choice of variables is based on the literature review we briefly summarized in Section 2.3. In particular, we expect that young and dynamic firms (the variable *age*), foreign firm ownership (the variable *foreign*), a production process standard certification that is validated by international organizations such as ISO9000 (the variable *ISO*), a high level of education of workers (the variable *skillsworkers*) and a competitive market environment (the variable *comp*) can encourage the adoption of technologies and practices aimed at reducing energy intensity. Therefore, we expect a negative sign of the coefficients associated to these firm characteristics. On other hand, we expect a reduction in energy efficiency due to barriers to the adoption of energy savings technologies such as telecommunications (the variable *hightelecom*) and credit access (the variable *highconscredit)* and, as a consequence, a positive sign of coefficients associated to these variables in our estimations.

We use firm-level data from the World Bank Enterprise Surveys for 24 developing countries (see Annex II for a full list of countries) for which data are available in order to run our regressions. For 15 countries (Benin, Brazil, Ecuador, El Salvador, Ethiopia, Guatemala, Honduras, India, Nicaragua, Peru, South Africa, Sri Lanka, Tanzania, Thailand and Viet Nam), we can run a 3-year panel analysis, for 9 countries data are available only for cross-country analysis . (Bangladesh, Costa Rica, Egypt, Guyana, Indonesia, Madagascar, Malawi, Mauritius, Pakistan). We use simple pooled panel analyses as we treat X and Z variables (except the variable age) as time invariant and cross firms' fixed effects estimations are technically infeasible. For each regression we use robust standard errors to correctly apply the usual t-tests. We also estimate an EKC in which the estimated equation takes the following traditional form:

$$\left(\frac{E}{L}\right)_{it} = \alpha_1 + \alpha_2\left(\frac{Y}{L}\right)_{it} + \alpha_3\left(\frac{Y}{L}\right)_{it}^2 + \alpha_4\left(\frac{K}{L}\right)_{it} + X_{it}\beta_1 + Z_{it}\beta_2 + \lambda + u_{it} \qquad (2)$$

Equation 2 is similar to equation 1. The main difference is that on the left hand side, the dependant variable is energy per capita (not energy intensity) and on the right hand side, the main explanatory variable is output per capita (in a quadratic form) as explained by the traditional EKC literature. No variable is expressed as a logarithm as in many EKC contributions (Torras and Boyce 1995; Richmond and Kaufmann 2005). Again λ denotes dummy variables representing the economic sector where the firm is active. The EKC hypothesis assumes a bell-shaped relationship between energy per capita and output per capita represented by a parabolic function. Therefore, we can claim EKC evidence when α_2 shows a positive sign and α_3 a negative one and both coefficients are significant. We will test this hypothesis for all 24 countries.

Finally, we highlight the specific relationship between productivity (TFP) and energy intensity and use non-parametric techniques to examine the path of the relationship in firms. Our aim is to verify whether the results derived from regressions are robust to an estimation technique that is not constrained to a selected model specification. In particular, we use a kernel estimation technique (Wand and Jones 1995). This technique allows to interpolate sub-samples of data rather than the entire sample set as in the linear regression technique and thus represents a more flexible specification. Plots are smoothed according to a specific parameter k that we set at a specific level (k=50) in almost all cases, except for a few countries according to the sample structure.

4. Results

We focus on each specific explanatory variable of the level of energy intensity. Each group of variables deserves separate discussion.

The *TFP* is the core variable of our analysis and we estimate this as a first step. As the reader can verify from the estimations tables contained in Annex IV, we find a negative and significant sign of the coefficient associated with the TFP variable for almost all countries. The result is robust to the different size and geographical position of countries. When we adopt non-parametric estimations (Annex V), the path of the relationship between TFP and energy per output decreases in nearly all countries (Bangladesh, Guyana Tanzania and Mauritius are exceptions).

The findings are very interesting and suggest that technological change and productivity factors generate energy efficiency. This is the only variable for which we find robust evidence as a determinant of energy efficiency. For all other variables, the results are more ambiguous. From a policy perspective, this result is very relevant as it suggests that actions aimed at improving the productivity of firms are win-win, as they also generate energy savings. Firms that adopt innovative strategies to enhance output are more likely to manage energy inputs with more efficiency and this is good news from a policy perspective. We do not have enough evidence to show that the causal relationship moves from technological change to energy efficiency or rather, the other way around (or both). This is an issue that could be explored more in depth with direct interviews in developing countries` firms at the second phase.

Capital per capita shows a negative sign and is significant only in 10 countries out of 24 including Brazil, Viet Nam and Thailand. In those countries with a growing market, big firms have more opportunities to reduce energy intensity. When we consider *firm characteristics*, the results are even more ambiguous. The hypothesis that young firms rather than old ones are more dynamic and ready to adopt new technologies is not supported by data, as the variable *age* in most cases is not significant. Except in some notable cases such as Ecuador, Pakistan and Viet Nam, quality certifications (*ISO9000* in our analysis) are not related to energy efficiency. This can mainly be explained by two factors. The first motivation is technical, as for many countries we have a restricted dataset. The second motivation is that ISO9000 is a process certification that guarantees the quality of the firm organization system and its capability to provide a product that matches the customers' needs. Environmental and energy efficiency targets might not be part of the strategy of well-organized firms. In Brazil, ISO9000 certified firms are even less environmentally friendly. Similarly, only in a few cases *competitors* and market pressures induce firms to adopt virtuous behaviour aimed at saving costs and at promoting energy efficiency (Indonesia, Honduras, El Salvador, Pakistan, Thailand). *Foreign ownership* can encourage environmental friendly behaviours of firms in several countries such as El Salvador, Guatemala, Ethiopia, Viet Nam, Peru and Sri Lanka.

The effects of business constraints variables are also mixed. Whereas for India and Guatemala, *telecommunications business barriers* increase energy consumption, the opposite effect is found in Egypt and Viet Nam. This contradiction can be explained by different behaviours adopted by firms to tackle market failures. On the one hand, barriers to communication flow may represent an obstacle to innovation and limit the adoption of energy saving technologies. On other hand, high telecommunications barriers may induce firms to stimulate business by pursuing cost savings and energy efficiency that they can control with more effectiveness rather than infrastructural facilities. Similar results are found for *credit access business barriers.*

Moreover, we find large differences between *industrial sectors* (see Annex VI). The garments (India, Malawi, Peru), leather (in Brazil, Ethiopia, Madagascar and Nicaragua), chemicals (in Bangladesh, Benin, Egypt, El Salvador, Guyana and Tanzania) and paper sectors (in Costa Rica, Guatemala and Mauritius) are those with the lowest level of energy per output. This result confirms that the structural composition of economies plays a relevant role in affecting energy intensity in developing countries. A well-driven policy design should also be based on research addressing the macroeconomic conditions of each country by encouraging low energy intensity activities in those countries where their contribution to national output is small. If we examine results concerning dummy variables for sectors that we investigate with our OLS estimations, the interpretation is not always straightforward. Results are often not significant and the sign is different across estimations. This may be attributable to many reasons. First, the sectoral composition of the sample differs among countries. Second, when we use dummy variables for OLS estimations, one or more sectoral dummies should be dropped to avoid the dummy trap. The dropped dummy variables act as benchmarks to interpret the sign of the coefficients associated with the other sectors and are, of course, different between countries. Third, the number of observations between countries varies and may affect the reliability of estimations. In spite of these serious drawbacks, we find that some sectors are generally less energy efficient than others. The food sector shows a positive and significant sign for 14 regions, the textile sector for 9 regions, the wood sector and the plastic sector for 8 regions. Results should be interpreted case by case and more in-depth analyses are needed to investigate this issue in more detail, but an interesting finding is that the sectoral economy in developing countries can play a role to affect energy intensity and some sectors are more likely than others to be inefficient.

Finally, we test the EKC hypothesis for energy intensity at the firm level. Annex VIII suggests that 10 counties out of 24 show the expected coefficient signs and significance. Weak evidence is found for most countries including Thailand, Indonesia, India and Tanzania. This finding supports previous studies (Dijkgraaf and Vollebergh 2005) that deny a homogenous pollution-income path for countries and indicates differentiated growth paths among developing countries. Results suggest that countries with an EKC would not need tight policies to promote environmental friendly technologies but their economies could endogenously reach a virtuous growth path focussed on an energy intensity reduction. In countries such as India, policymakers should play a stronger role in encouraging the adoption of energy savings methods of production. The reader should note that our EKC equation includes energy spending per capita and not energy consumption. As noted by Common (1995), improvements in energy intensity may not always correspond to improvements in environmental degradation. Policymakers should consider that in this case, the two targets could be delinked. Nonetheless, the results that confirm the existence of a Kuznetz curve at the micro level in several countries are very interesting and contrast with macro-level evidence over time.

5. Conclusions and suggestions for phase 2

This paper uses careful econometric analyses to understand the determinants of energy efficiency for developing countries. We find robust evidence that productivity (which can be interpreted as technological change) and energy efficiency are strongly related. This result is complemented by evidence which indicates weak support for the EKC hypothesis in many developing countries when we consider the relationship between energy intensity and output at the firm level. Moreover, sectoral distribution of the national economy matters for determining energy efficiency. Finally, we find ambiguous results that a set of firm characteristics and business constraints affect energy intensity and the sign of their impact is not clear.

From a policy perspective, two insights emerge. First, evidence supports the claim that policies addressed to improve productivity could be win-win, as they could also improve energy intensity. Second, the country-specific results point to the need to implement policies that consider unique economic and social conditions in each country. Our results suggest a different sign of the impact of business constraints and firm characteristics in different contexts and this finding requires taking a closer look at measures to tackle these factors in each situation.

Our analysis suggests the need for further research into understanding energy intensity determinants. The research could be widened at micro and macro level. At micro level it could be very interesting to study more in depth the factors that condition the adoption of environmental friendly and cost saving technologies in each firm. Our analysis based on World Bank Data does not satisfactorily answer all questions concerning the barriers to innovation and factors determining energy intensity. Direct interviews with local experts in developing countries could be very useful to fill the gap. Interviews could also be useful to analyse in depth the endogeneity issue of the relationship between energy efficiency and productivity. In our model we assumed that productivity affects energy efficiency, but it would be interesting to investigate the existence of the opposite relationship as in Adenikinju and Alaba (1999).

Moreover, our analysis shows the need to carry out a complementary analysis focussing on macroeconomic issues. Our results indicate that the structural composition of each developing country matters for determining energy intensity, and a macroeconomic analysis run by macro sectoral data could shed light on the path of energy intensity in each country. The shift share technique (Esteban 2000) could be a very useful tool to study the dynamics of energy intensity of each country over time (for those countries with data). This is a technique that allows verification of discrepancies among regions in terms of energy intensity's dependency on their structural composition (low energy intensive vs high energy intensive economies) or of inefficiencies (high energy demanding vs low energy demanding countries). Country examples could include South Africa, Brazil, Viet Nam, Tanzania and Indonesia.

Finally, from a macroeconomic perspective it would be interesting to investigate the EKC hypothesis for a selection of developing countries. As we mentioned previously, verification of EKC existence relates to a proper approach to tackle environmental degradation. An analysis of the relationship between growth and energy intensity within a "macro" perspective could complement results deriving from this analysis and would provide interesting and useful insights from a policy perspective.

A mix of qualitative and quantitative analyses could represent valuable tools for interesting further developments of the current work that, at this stage, has already produced useful information and raised intriguing research questions. Annex X contains an attempt outline of the work that could be developed in phase 2 of the project.

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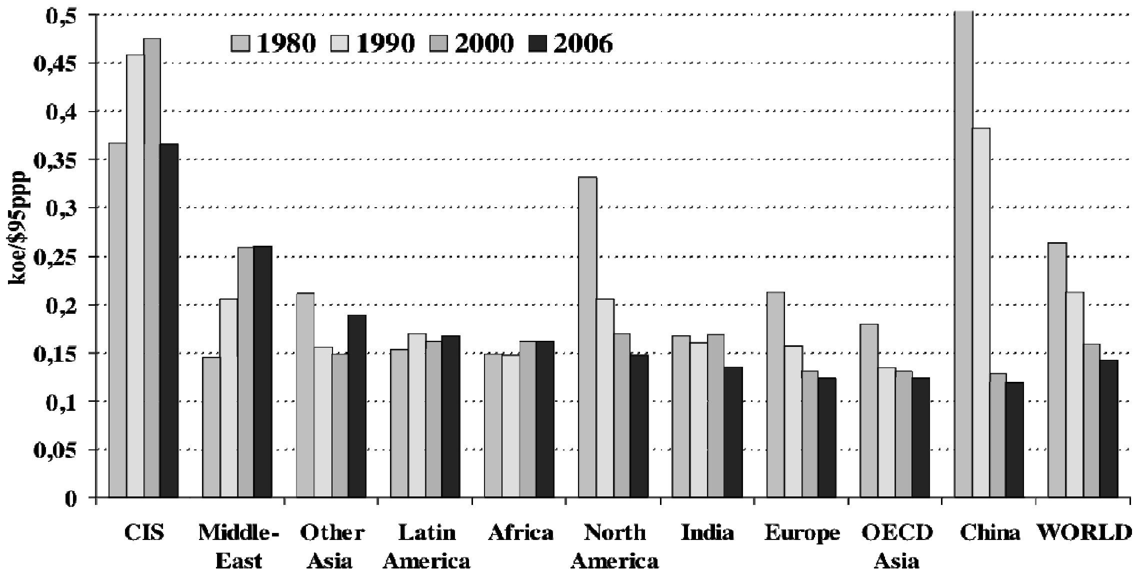
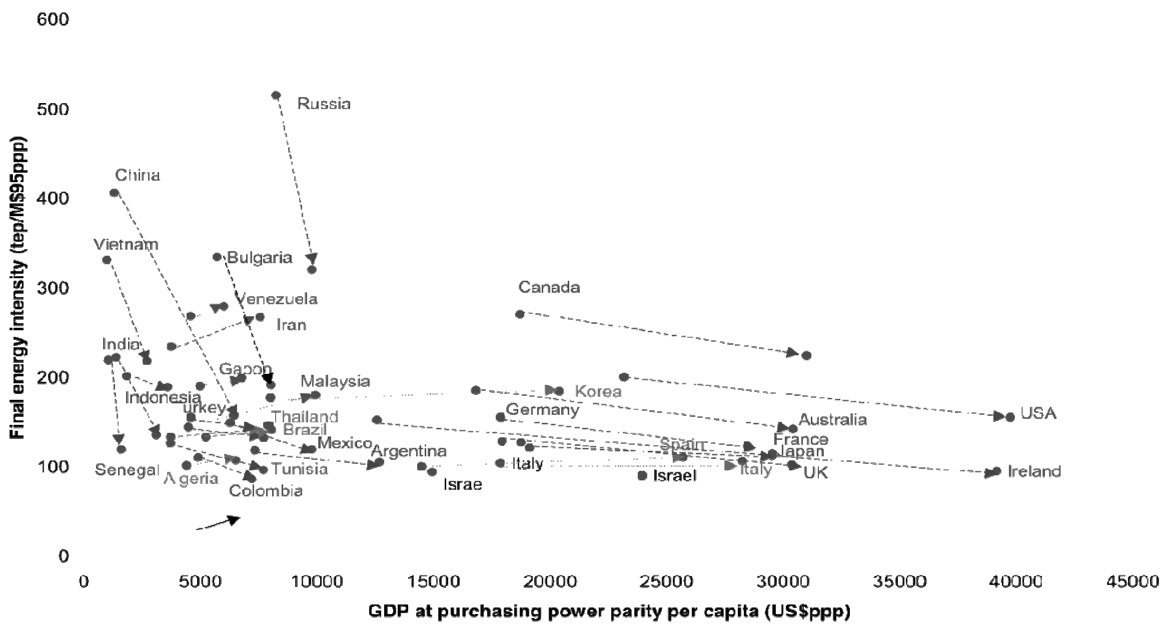
Annex I. Evidence about the path of energy intensity in the world

Figure A1: Energy intensity of industry



Source: WEC, 2008:26.

Figure A2: Trends in final energy intensity and GDP per capita (1990–2006)



Source: WEC, 2008:23.

Annex II. List of countries included in analysis

Bangladesh (BGD)
Benin (BEN)
Brazil (BRA)
Costa Rica (CRI)
Ecuador (ECU)
Egypt (EGY)
El Salvador (SLV)
Ethiopia (ETH)
Guatemala (GTM)
Guyana (Guy)
Honduras (HND)
India (IND)
Indonesia (IDN)
Madagascar (MDG)
Malawi (MWI)
Mauritius (MUS)
Nicaragua (NIC)
Pakistan (PAK)
Peru (PER)
South Africa (ZAF)
Sri Lanka (LKA)
Tanzania (TZA)
Thailand (THA)
Viet Nam (VNM)

Annex III. List of economic sectors included in analysis

Textiles,
Leather
Garments
Agro-industry
Food
Beverages
Metals and machinery
Electronics
Chemical and pharmaceuticals
Construction
Wood and furniture
Non-metallic and plastic materials
Paper
IT services
Other man.
Telecommunications
Accounting
Advertising
Other services
Retail trade
Hotels and restaurants
Transport
Real estate
Mining
Auto
Sport

Annex IV. Results of pooled panel and cross-firm OLS estimations

Energy efficiency and productivity

	(BGD)	**(BEN)**	**(BRA)**	**(CRI)**
Log of capital per worker [ln(K/L)]	.084	-0.125	-.200***	-.111
Ln(TFP)	-0.414***	-0.498***	-.530***	-.730***
Constant	-5.048***	-3.849**	-4.128***	-4.70***
hightelecom	-0.301	.091	.088	.197
highconscredit	.224	-.014	-.018	.030
ISO		.221	.209***	-.058
age	.008	.003	.001	.000
comp				
skillsworkers		.006	-.003	-.002
foreign ownership		.604*	.000	-.123
Industry dummy variables	yes	yes	yes	yes
Year	2002	2002-2004	2001-2003	2005
Observations	92	110	4172	270
R square	0.474	0.245	0.207	0.235

Notes: Dependent variable is log of energy consumption per sales; Output is defined as total sales; Industry dummy variables; *, ** and *** indicate significance at 10, 5 and 1 percent, respectively. Robust standard errors.

Energy efficiency and productivity

	(ECU)	**(EGY)**	**(SLV)**	**(ETH)**
Log of capital per worker [ln(K/L)]	-.119**	-.144***	-.897***	-.015
Ln(TFP)	-.298***	-.588***	-3.461***	-.575***
Constant	2.806***	-3.343***	3.441***	-4.510***
hightelecom	.360**	-0.994**		.112
highconscredit	-.372**	.054	1.210***	-.448***
ISO	-.464*	-0.274	5.063***	.576***
age	.008	-.000	-.012	
comp			-0.46***	
skillsworkers	.014***	-.001	.044***	
foreign ownership	-.357	-.026	-2.212***	-1.369**
Industry dummy variables	yes	yes	yes	yes
Year	2001-2003	2004	2001-2003	2000-2002
Observations	553	488	32	375
R square	0.073	0.261	0.941	0.452

Notes: Dependent variable is log of energy consumption per sales; Output is defined as total sales; Industry dummy variables; *, ** and *** indicate significance at 10, 5 and 1 percent, respectively. Robust standard errors.

Energy efficiency and productivity

	(GTM)	(GUY)	(HND)	(IND)
Log of capital per worker [ln(K/L)]	-.123**	.209*	.031	-.070**
Ln(TFP)	-.686***	-.289	-.590***	-.508***
Constant	-3.075***	-6.907***	-4.533***	-3.727***
hightelecom	.470***	-.017	-.021	.301***
highconscredit	.038	-.257	.002	-.042
ISO	-.028	-.153	-.246	
age	-.001	.003	.006	.003*
comp	.000		-.001***	
skillsworkers				-.003**
foreign ownership	-.348*	1.525**	.151	-.058
Industry dummy variables	yes	yes	yes	yes
Year	2001-2003	2004	2001-2003	2000-2002
Observations	710	128	519	2558
R square	0.266	0.212	0.213	0.198

Notes: Dependent variable is log of energy consumption per sales; Output is defined as total sales; Industry dummy variables; *, ** and *** indicate significance at 10, 5 and 1 percent, respectively. Robust standard errors.

Energy efficiency and productivity

	(IDN)	(MDG)	(MWI)	(MUS)
Log of capital per worker [ln(K/L)]	-.130	-.083	-.205***	-.038
Ln(TFP)	-.434***	-.465***	-.545***	-.640***
Constant	-1.524	-3.22***	-2.604***	-3.460***
hightelecom	-.449	.063	-.198	.096
highconscredit	.292	.335*	.140	-.299
ISO	-.251	.848**	.029	.618**
age	-.019**	.005	.007	-.016**
comp	-.003**			
skillsworkers	0.008***	.007		-.035
foreign ownership	-.058	.155	.277	-.189
Industry dummy variables	yes	yes	yes	yes
Year	2003	2005	2005	2005
Observations	179	88	132	48
R square	0.181	0.484	0.324	0.461

Notes: Dependent variable is log of energy consumption per sales; Output is defined as total sales; Industry dummy variables; *, ** and *** indicate significance at 10, 5 and 1 percent, respectively. Robust standard errors.

Energy efficiency and productivity

	(NIC)	**(PAK)**	**(PER)**	**(ZAF)**
Log of capital per worker [ln(K/L)]	.138***	-.051	.416*	-.178**
Ln(TFP)	-.601***	-.554***	-1.092***	-.630***
Constant	-4.318***	-2.723***	-5.270***	-3.969***
hightelecom	.034	-.048	-.576	.191
highconscredit	-.186**	-.156*	-.896**	-.320
ISO	.141	-.354***		.005
age	-.002		-.037	.001
comp	-0.000	-.000**		.002
skillsworkers		-.003	.060	.004
foreign ownership	.120	.470	-1.704***	.099
Industry dummy variables	yes	yes	yes	yes
Year	2001-2003	2002	2000-2002	2001-2003
Observations	598	822	38	598
R square	0.314	0.349	0.869	0.223

Notes: Dependent variable is log of energy consumption per sales; Output is defined as total sales; Industry dummy variables; *, ** and *** indicate significance at 10, 5 and 1 percent, respectively. Robust standard errors.

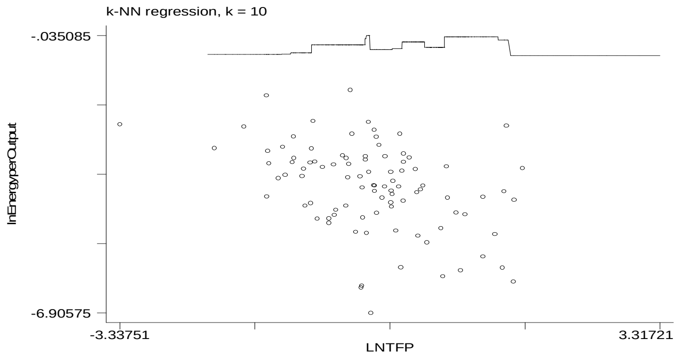
Energy efficiency and productivity

	(LKA)	**(TZA)**	**(THA)**	**(VNM)**
Log of capital per worker [ln(K/L)]	-.062	-.099	-.151***	-.077**
Ln(TFP)	-.405***	-.781***	-.506***	-.590***
Constant	-3.427***	.384	-3.737***	-3.184***
hightelecom	-.093	-.960	.068	-.256**
highconscredit	.193	1.404***	-.018	.109*
ISO		.053	-.071	-.217***
age	-.007	-.060***	.007***	.004**
comp	.001*		-.006***	
skillsworkers	-0.009	-.055**	-.001	-.011***
foreign ownership	-1.050***	-.050	.196***	-.475***
Industry dummy variables	yes	yes	yes	yes
Year	2002-2004	2001-2003	2002-2004	2003-2005
Observations	241	45	3071	2380
R square	0.267	0.815	0.265	0.199

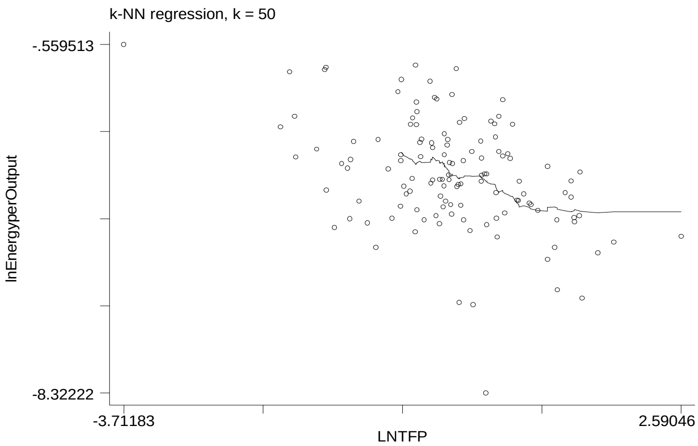
Notes: Dependent variable is log of energy consumption per sales; Output is defined as total sales; Industry dummy variables; *, ** and *** indicate significance at 10, 5 and 1 percent, respectively. Robust standard errors.

Annex V. Energy efficiency vs productivity. A non-parametric estimation

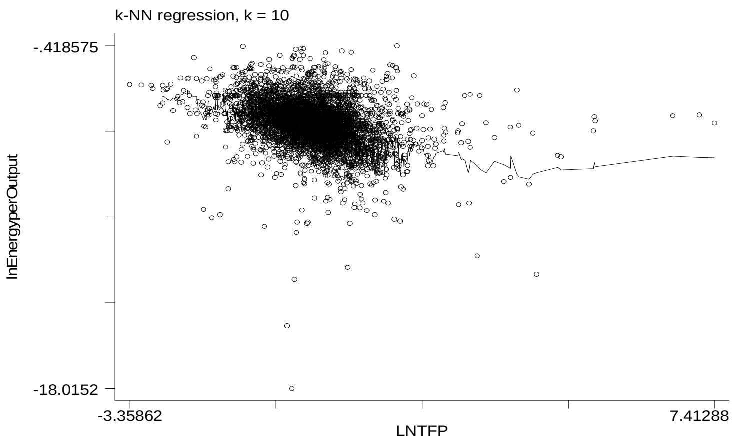
Bangladesh



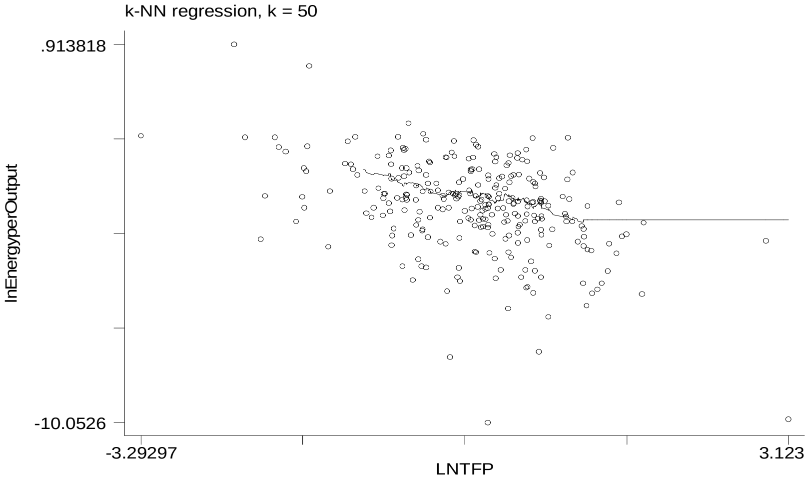
Benin



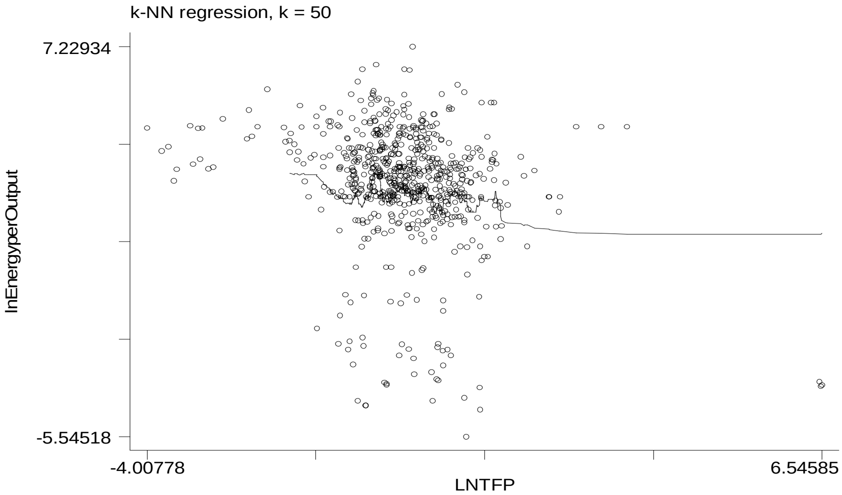
Brazil



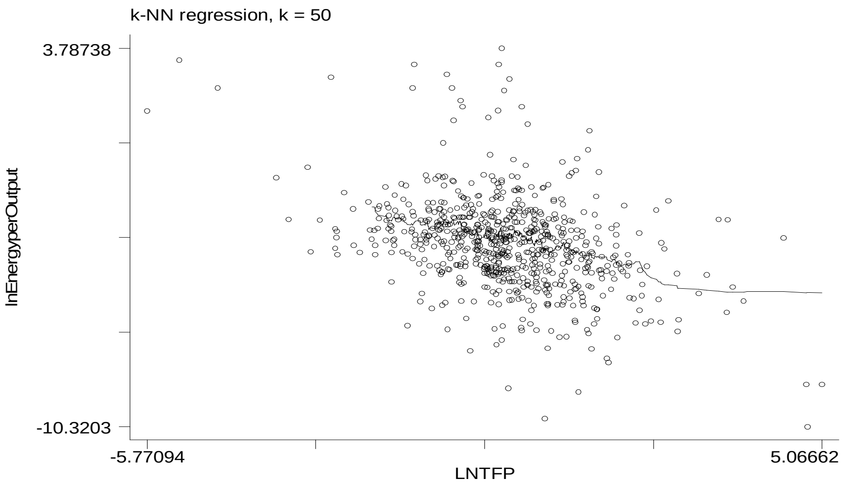
Costa Rica



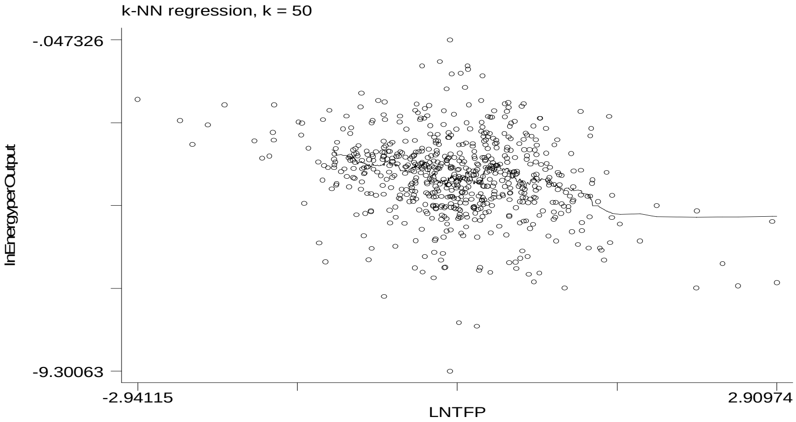
Ecuador



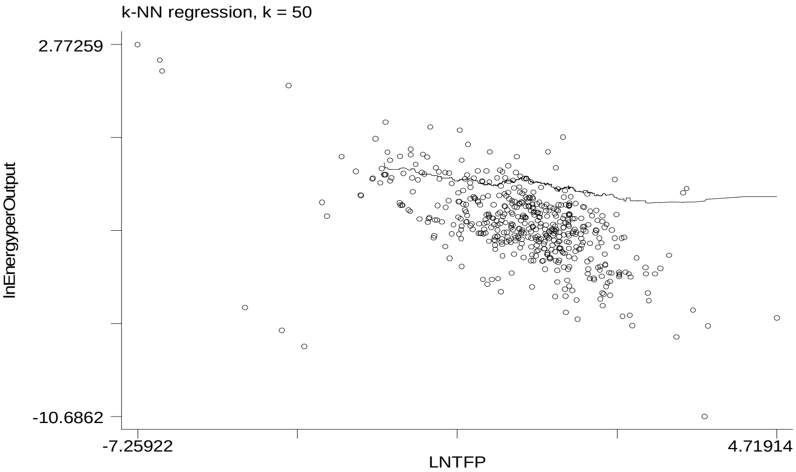
Egypt



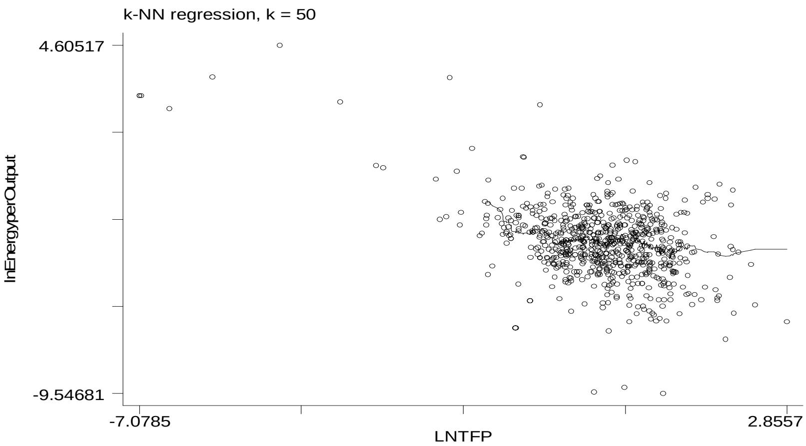
El Salvador



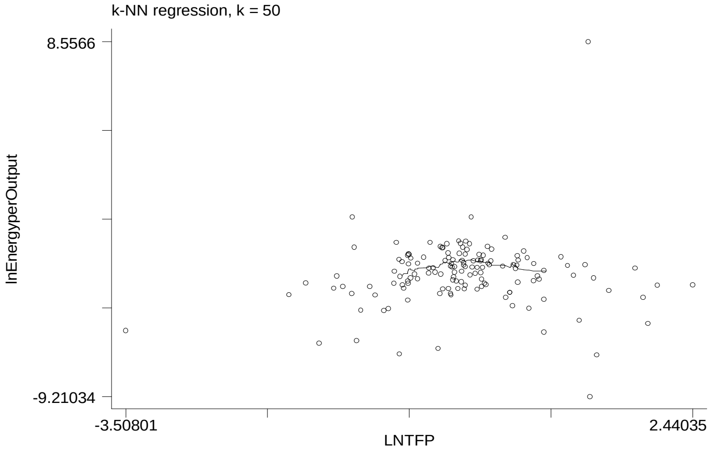
Ethiopia



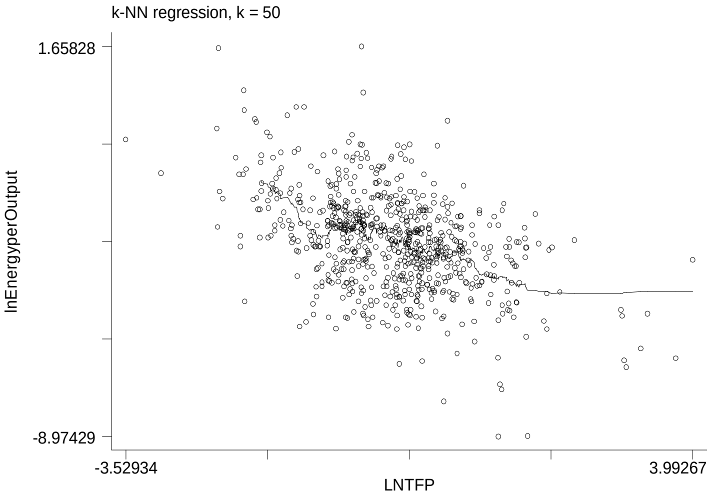
Guatemala



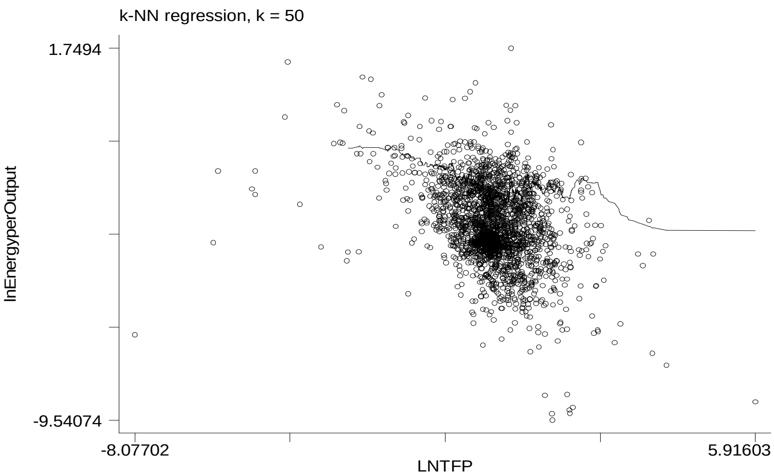
Guyana



Honduras



India



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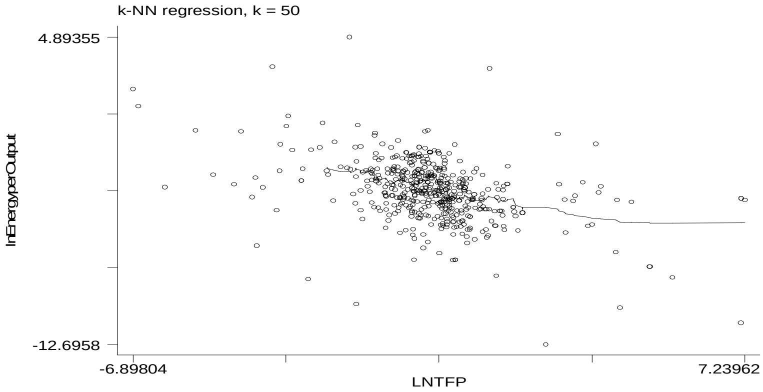

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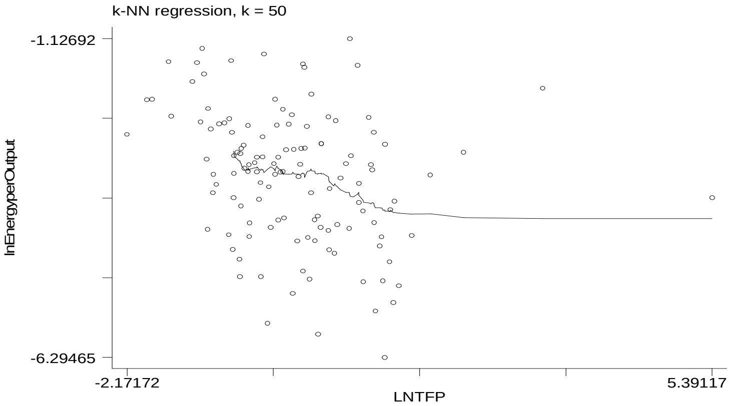
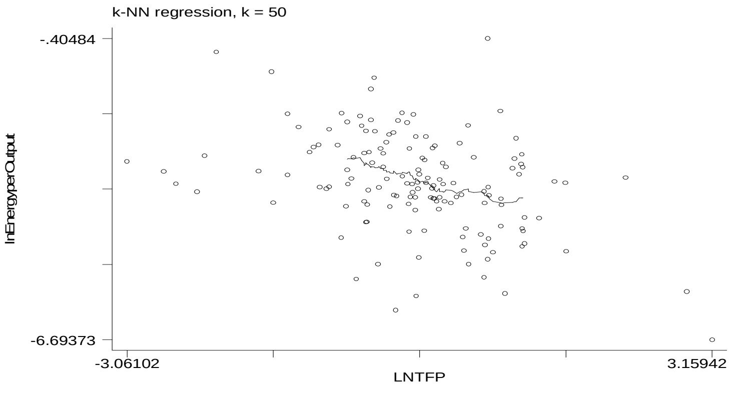
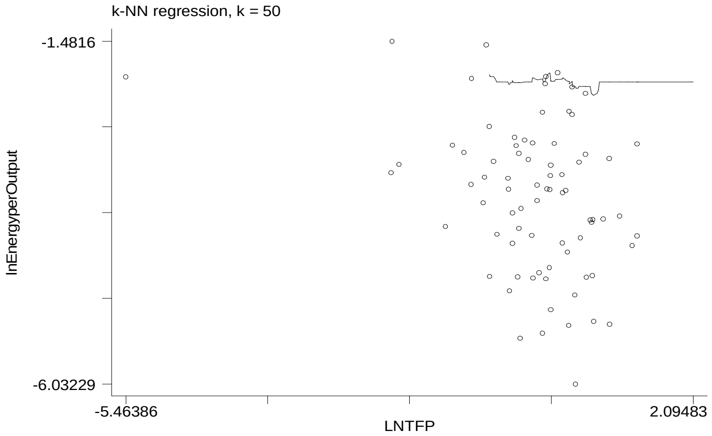


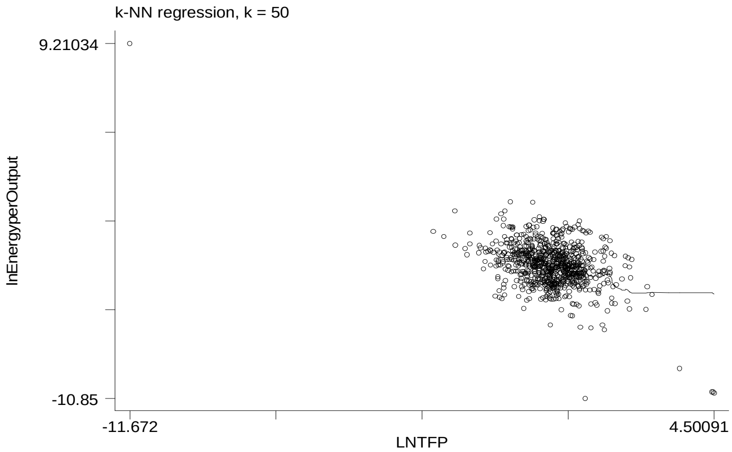
Malawi



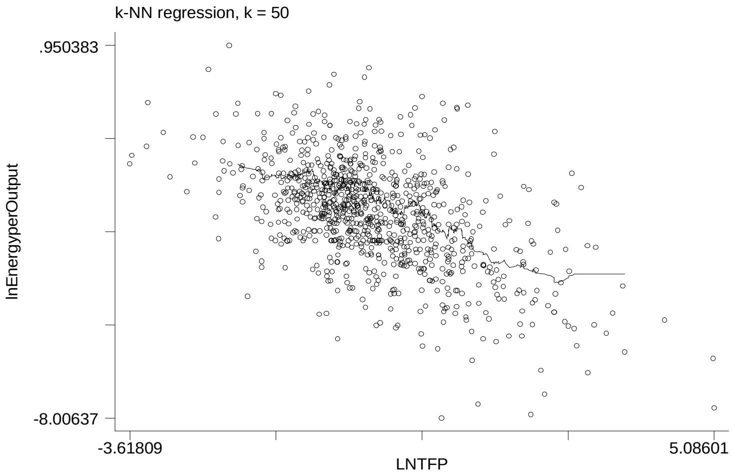
Mauritius



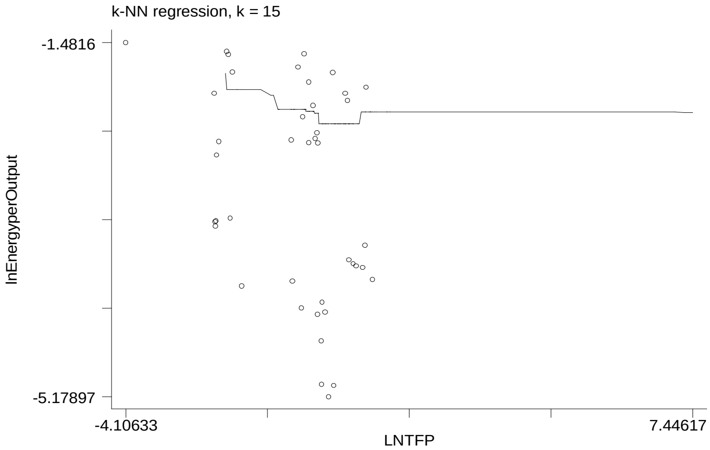
Nicaragua



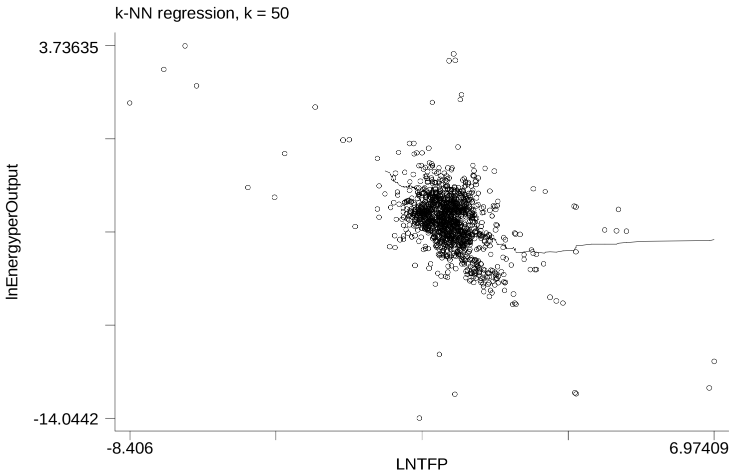
Pakistan



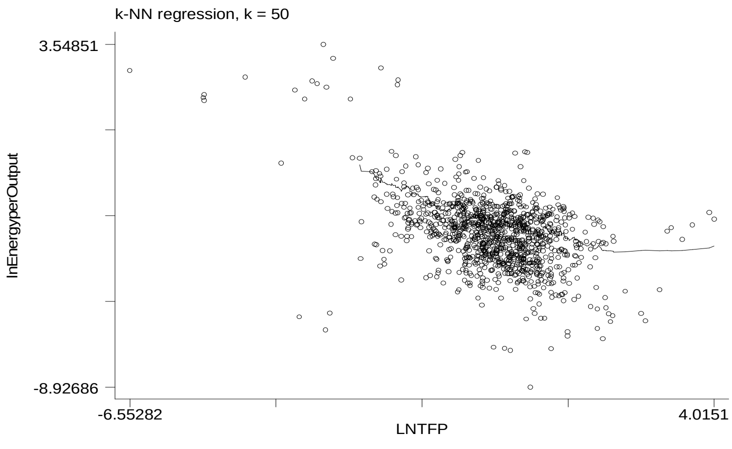
Peru



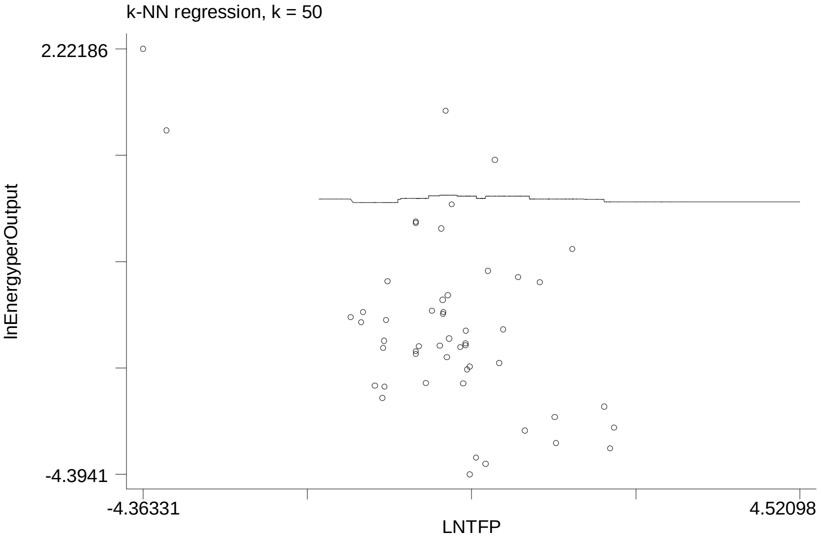
South Africa



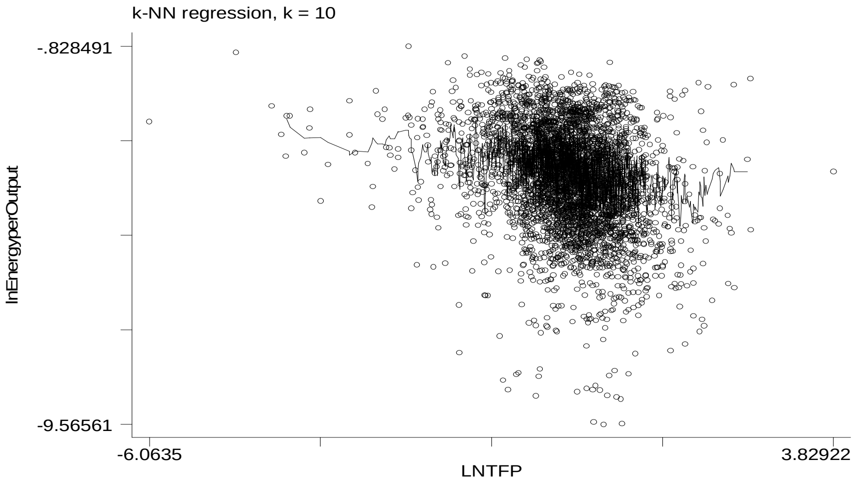
Sri Lanka



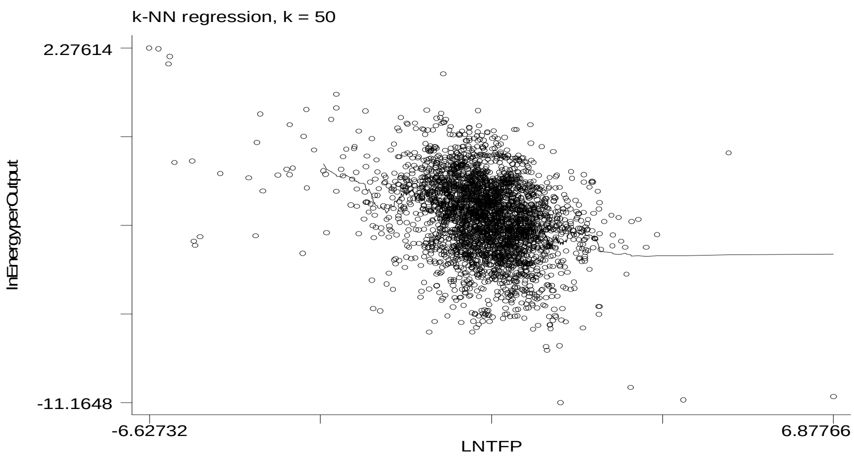
Tanzania



Thailand



Viet Nam



Annex VI. Energy/sales per country and sector (in bold the sector showing the lowest mean energy intensity)

	BGD		BEN		BRA		CRI		ECU		EGY	
	Mean	**Obs**	**Mean**	**Obs**	**Mean**	**Obs**	**Mean**	**Obs**	**Mean**	**Obs**	**Mean**	**Obs**
Textiles	.049	48	.136	3	.054	288	.021	17	78.5	71	.131	137
Leather	.027	6			.017	469	.029	7	31.6	36	1.16	42
Garments	.022	21			.021	1250	.029	25	30.1	47	.363	114
Agro-industry			.120	37								
Food	.055	6			.030	334	.039	35	58.7	139	.345	146
Beverages							.065	6	148.8	42		
Metal			.052	43	.016	523	.039	41	39.8	138	.608	162
Electronics	.030	3			.020	206	.016	2	36.5			
Chemical	.019	11	.019	8	.028	241				141	.060	63
Construction			.061	9								
Wood			.068	84	.025	876	.048	44	26.9	57	.103	57
Plastic			.048	2			.079	67	44.2	78	.558	157
Paper							.010	2				
IT												
Other manufacture							.070	38			1.42	39
Telecommunications												
Accounting												
Advertising												
Other services												
Retail trade												
Hotels &restaurants												
Transport												
Real estate												
Mining												
Auto					.024	372	.057	3			.462	12
Sport												
Others												

	SLV		ETH		GTM		GUY		HND		IND	
	Mean	**Obs**	**Mean**	**Obs**	**Mean**	**Obs**	**Mean**	**Obs**	**Mean**	**Obs**	**Mean**	**Obs**
Textiles	.048	25	.057	14	.121	38	.042	6	.053	23	.112	488
Leather	.026	31	.018	38	.044	8					.035	129
Garments	.047	180	.049	47	.657	213	.031	10	.055	111	.021	654
Agro-industry												
Food	.040	187	.066	111	.074	140	.081	81	.088	178	.062	394
Beverages	.040	12	.026	18	.041	17			.164	42		
Metal	.049	141			.048	68			.055	61	.062	324
Electronics											.050	593
Chemical	.021	82			.974	58	.029	4	.279	34	.085	746
Construction												
Wood			.165	303	.457	100	121.04	43	.067	202		
Plastic	.066	146			.063	100			.089	112		
Paper					.026	8						
IT											.062	7
Other manufacture			.059	45	.041	12			.030	18		
Telecommunic.												
Accounting												
Advertising												
Other services												
Retail trade												
Hotels &restaurants												
Transport												
Real estate												
Mining												
Auto											.055	636
Sport												
Others												

	IDN		MDG		MWI		MUS		NIC		PAK	
	Mean	**Obs**	**Mean**	**Obs**	**Mean**	**Obs**	**Mean**	**Obs**	**Mean**	**Obs**	**Mean**	**Obs**
Textiles	.839	173	.088	23	.047	12	.044	22	.051	23	.114	313
Leather			.024	5					.020	67	.071	39
Garments	.052	143	.076	41	.012	3			.054	96	.079	134
Agro-industry	.047	17			1.71	1						
Food	.132	104	.094	32	.073	53	.055	17	.083	131	.120	146
Beverages	.196	16	.284	1			.083	3	.157	44		
Metal	.019	2	.055	15	.060	20	.150	7	.052	87		
Electronics	.024	33			.023	1					.087	96
Chemical	.735	74	.035	15	.024	18	.054	8	.041	80	.070	137
Construction			.104	1	.038	2						
Wood	.969	51	.060	46	.037	21	.025	4	.075			
Plastic			.059	9	.062	19	.101	1	.076	133		
Paper	.049	27	.080	4	.025	3	.022	12	.122	5		
IT											.021	51
Other manuf.			.043	29	.039	1	.950	7	454.5	22		
Telecommunic.												
Accounting												
Advertising												
Other services												
Retail trade												
Hotels &restaurants												
Transport	.032	18										
Real estate												
Mining												
Auto	.101	17										
Sport											.055	44
Others												

	PER		ZAF		LKA		TZA		THA		VNM	
	Mean	**Obs**	**Mean**	**Obs**	**Mean**	**Obs**	**Mean**	**Obs**	**Mean**	**Obs**	**Mean**	**Obs**
Textiles	.124	13	.020	51	.089	188	.287	8	.067	558	.025	228
Leather	.194	3	.007	20			.113	6			.047	72
Garments	.049	14	.105	61	.081	357	1.31	3	.017	504	.030	216
Agro-industry							.784	18				
Food	.084	3	.124	140	.288	430			.036	533	.042	502
Beverages											.047	27
Metal	.096	8	.037	292	.033	85	.134	9	.023	529	.068	530
Electronics			.010	16					.034	496	.022	57
Chemical	.090	14	.016	129			.026	3			.104	196
Construction							.069	2				
Wood	.161	18	.198	233			.483	5	.027	372	.052	393
Plastic	.115	14	.123	135	2.60	108	.084	3	.052	717	.061	476
Paper			1.85	38			.266	3			.035	175
IT			.001	3								
Other manuf.			.013	215							.058	340
Telecommunic.												
Accounting												
Advertising												
Other services												
Retail trade			.014	4								
Hotels &restaurants			.004	3								
Transport												
Real estate												
Mining			.131	6								
Auto									.032	433		
Sport												
Others					.001	3						

Annex VII. Pooled and cross-firms OLS regressions. Sectoral dummy variables coefficients and their significance

	BGD	BEN	BRA	CRI	ECU	EGY	SLV	ETH
Textiles	.99***	1.4	1.4***	.70	.01	.43*	-4.6***	.98**
Leather	.75	.97		.87	.14	1.3*		
Garments	-.13		.06	.87		-.05	-6.3***	.51**
Agro-industry	.62							
Food			.72***	1.4**	.33	.62**	-2.3***	1.6***
Beverages				2.1***	-.10			
Metal		1.3**		1.1*	-.23	-.07	-3.1***	
Electronics	1.2*		.11					
Chemical			.66***		-.28			
Construction		1.1						
Wood		1.3**	.30***	1.1*				.97***
Plastic		.55*		1.3**	-.15	.90***	-4.6***	
Paper								
IT								
Other manuf.				1.3**		.12		.41
Telecommunic.								
Accounting								
Advertising								
Other services								
Retail trade								
Hotels &restaurants								
Transport								
Real estate								
Mining								
Auto			.52***	1.1		.53		
Sport								
Others								

	GTM	GUY	HND	IND	IDN	MDG	MWI	MUS
Textiles	.42	.12	.87**	.66***	-.41	-.83*	-.11	.68
Leather	-.23							
Garments	.01	-.37	.88**		-1.3*	.08		
Agro-industry					-.72			
Food	.53**	.61	.62**	.48***	-.76	.94***	.70***	.77
Beverages	-.60		1.12***		1.1			.89
Metal	.23		.77**	.64***		.35	.09	-.47
Electronics				.24***	-.50		.00	
Chemical	-.07		.07	.83***	-.61			1.5***
Construction						.15	.55	
Wood	.25	1.1***	.67**		-.99	-.18	-.22	
Plastic	.32		.57			.31	.57**	
Paper					-.74	1.0		
IT				1.7***				
Other manuf.	-.42					-.49	1.5***	.45
Telecommunic.								
Accounting								
Advertising								
Other services								
Retail trade								
Hotels &restaurants								
Transport								
Real estate								
Mining								
Auto				.41***	-.22			
Sport								
Others								

	NIC	PAK	PER	ZAF	LKA	TZA	THA	VNM
Textiles	.50**	.78***	.31	.33*	.40	-1.3***	1.3***	-.49**
Leather		.23						-.55*
Garments	.25	.37**		-.66**	.29	1.5		-.60***
Agro-industry						-1.0**		
Food	.55***	.94***	-.08	.69***	1.0***		.87***	.21
Beverages	1.55***							.30
Metal	.60***			.48***		-3.0***		.40**
Electronics		.38**					.57***	
Chemical		.22	-.80	.24				.43*
Construction								
Wood	.67			.43***		-.09	.40***	-.37*
Plastic	.86***		.41	1.1***	.57		1.2***	.44**
Paper	1.7***			1.1*		1.5***		.17
IT								
Other manuf.	-.54							.36*
Telecommunic.								
Accounting								
Advertising								
Other services								
Retail trade				1.1***				
Hotels &restaurants								
Transport								
Real estate								
Mining				2.6***			.68***	
Auto								
Sport								
Others								

Annex VIII. Testing the Environmental Kuznets Curve hypothesis at the firm level. Sign and significance (5%) of the EKC coefficients

	α2	**α3**	**EKC**
Bangladesh	+ (non SIGNIFICANT)	- (non SIGNIFICANT)	NO
Benin	+ (non SIGNIFICANT)	- (non SIGNIFICANT)	NO
Brazil	+ (SIGNIFICANT)	- (SIGNIFICANT)	YES
Costa Rica	+ (SIGNIFICANT)	- (non SIGNIFICANT)	NO
Ecuador	+ (SIGNIFICANT)	- (SIGNIFICANT)	YES
Egypt	+ (non SIGNIFICANT)	- (SIGNIFICANT)	NO
El Salvador	- (non SIGNIFICANT)	+ (non SIGNIFICANT)	NO
Ethiopia	- (SIGNIFICANT)	+ (non SIGNIFICANT)	NO
Guatemala	+ (SIGNIFICANT)	- (SIGNIFICANT)	YES
Guyana	+ (SIGNIFICANT)	- (SIGNIFICANT)	YES
Honduras	- (non SIGNIFICANT)	+ (non SIGNIFICANT)	NO
India	+ (non SIGNIFICANT)	+ (non SIGNIFICANT)	NO
Indonesia	+ (non SIGNIFICANT)	- (non SIGNIFICANT)	NO
Madagascar	+ (non SIGNIFICANT)	+ (SIGNIFICANT)	NO
Malawi	+ (SIGNIFICANT)	- (SIGNIFICANT)	YES
Mauritius	- (non SIGNIFICANT)	+ (SIGNIFICANT)	NO
Nicaragua	+ (SIGNIFICANT)	- (SIGNIFICANT)	YES
Pakistan	+ (SIGNIFICANT)	- (SIGNIFICANT)	YES
Peru	+ (SIGNIFICANT)	- (SIGNIFICANT)	YES
South Africa	+ (SIGNIFICANT)	- (SIGNIFICANT)	YES
Sri Lanka	+ (non SIGNIFICANT)	- (SIGNIFICANT)	NO
Tanzania	+ (non SIGNIFICANT)	- (non SIGNIFICANT)	NO
Thailand	+ (SIGNIFICANT)	- (non SIGNIFICANT)	NO
Viet Nam	+ (SIGNIFICANT)	- (SIGNIFICANT)	YES

Annex IX. Description of variables

Variables	Variable name	Units	Question Code
Sales	sales	In 000 LCU[3)]	C274a1y
Number of workers [1)]	labour	Number	C262a1y
Capital[2)]	capital	In ‘000	C281a1y
Energy	energy	In 000 LCU	C74e1y
Sector	λ	Dummy variable	industry
Age of firm	age	Years	surveyyear-c201
Foreign ownership	foreign	Dummy variable	C203b
No. of competitors	comp	Number	C216a+c216a2+c216a3
Workers with at least 12 years of education	skillsworkers	percentage	C270d
Telecommunication business constraint	Hightelecom	Dummy variable	C218a
Credit access business constraint[4)]	Highconscredit	Dummy variable	C218k
ISO certification	ISO	Dummy variable	C257

Notes: 1) Number of workers includes permanent workers; 2) Capital is the gross value of plant, property and equipment; 3) LCU=local currency units. 4) The variables C218a and C218k include 5 categories “No obstacle”, “Minor obstacle, “Moderate obstacle”, “Major obstacle” and “Very severe obstacle”. We create two binary dummy variables in which the first category is obtained by merging the categories “No obstacle”, “Minor obstacle”, “Moderate obstacle” and the second category by merging the categories “Major obstacle” and “Very severe obstacle”.

Annex X. Suggestions for the second phase of the project

Main duties	**Expected output**
Interviews with experts in a selected developing country to understand determinants of the energy efficiency technologies adoption in a relevant poor country (e.g., South Africa). The analysis could also be useful to understand the reciprocity of the relationship between total factor productivity and energy efficiency in developing countries Research questions. *What are the barriers to energy efficiency technological adoption?* *What is the nature of the relationship between technological change and energy efficiency?*	A document explaining the main elements explaining barriers to energy efficiency adoption and the causality of the relationship between energy intensity and total factor productivity from 10 interviews. Final workshop involving academic and policy operators.
A macroeconomic and sector analysis aimed at applying the shift share technique to understand the drivers of the differences concerning efficiency in energy consumption for a set of developing countries (e.g., 5 countries). Research question: *How can we explain differences in energy efficiency among developing countries?*	Short paper I part explaining the importance to analyse energy efficiency discrepancies among developing countries from a macroeconomic perspective, the methodological explanation of the shift and share methodology and results. Data source: IEA CD Rom about "Energy Statistics on non OECD countries" (2009) for data about energy consumption by sector and national sources for GDP by sector to calculate energy intensity in different developing countries.
A macroeconomic and sectoral analysis to investigate the EKC hypothesis for energy intensity at macro – level by investigating the relationship between energy intensity, GDP and other political and social indicators (e.g., human development index, political government etc.) for a set of developing countries (e.g., 15 countries). Research question: *Should energy efficiency pursued by fostering economic growth or by specific policies?*	Short paper II part containing a brief literature review about the EKC, the EKC literature referring to energy intensity and results about the EKC for a set of poor countries. Data source: IEA CD Rom about "Energy Statistics on non OECD countries" (2009) for energy intensity and IMF for data about GDP.

III. Profitability and energy efficiency: a firms' fixed effect approach

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Massimiliano Cali, Research Associate, Overseas Development Institute

1. Introduction

We investigate the relation between profitability and energy efficiency using a large sample of firms from 29 developing countries. This analysis complements the more common investigation of the relation between energy efficiency and productivity. Understanding the impact of energy efficiency on profitability is an important question in its own right given the high costs often involved in the adoption of energy saving techniques by firms. If increases in energy efficiency tend to have a positive effect on firm's profitability, switching to energy saving production technologies could become a more feasible investment option even in the presence of large adoption costs. In addition, the focus on developing countries allows the analysis to shed some light on the energy efficiency profitability relation in those contexts where the rate of energy saving adoption is lowest (and where most increase in energy consumption is expected in the future).

2. Data and variables

The data for the analysis come from various World Bank enterprise surveys, which are carried out regularly in a large number of developing countries (and in some high income countries as well). We select 29 developing countries which had enough data to run the analysis (see the Appendix for the selection of countries and cleaning of the data). The surveys of these countries were carried out between 2000 and 2005, with the majority of them concentrated in the period 2002-04 (which is a desirable feature for the cross-country comparability of the analysis). The data are collected at one point in time, but some of the questions asked to the firms refer to each of the previous three years. This allows separate entries for the key variables in our analysis in each of those years. Thereby we can construct a panel dataset spanning the three years preceding the survey year. As it turns out, this is an important characteristic of the data, which allows tackling several estimation problems.

The idea of the analysis is to examine the impact of energy efficiency on the profitability of the firm level controlling for a number of other factors that may influence this relationship. Let us define these two main variables first.

We rely on a standard definition of price-cost margin, defined as value added net of labour costs as a share of total production, to proxy for a firm's profitability. In particular we use:

π = (Total sales - raw materials - labour cost)/total sales

where all the variables are expressed in local currency units. Other than being quite a standard way of proxying for profitability (Li et al., 2004), this definition allows us to maximize the number of observation given the data available.[2]

Though there are several definitions of energy efficiency measures, "energy intensity measures are often used to measure energy efficiency and its change over time […] [E]nergy-intensity measures are at best a rough surrogate for energy efficiency. This is because energy intensity may mask structural and behavioural changes that do not represent "true" efficiency improvements" (EIA, 2003). Energy intensity is simply the ratio of energy input to industrial output; an economic-thermodynamic type of efficiency measure. Following Cantore et al. (2009), we also use a measure of energy intensity defined as:

e = Energy Consumed/Total Sales

where again all the variables are expressed in local currency units. We use the economic value rather than the physical value of production as no common physical unit at high level of industrial aggregation exists. This is also in line with the suggestion by Freeman et al. (1997).

Regarding the set of explanatory variables for profitability, there are two main strands of research examining the determinants of a firm's profitability (Kounetas and Tsekouras, 2008): the industrial organization and the strategic management literature. The traditional approach of the former is the Structure-Conduct-Performance (SCP) paradigm, which focuses both on industry-level determinants of competition (mainly industry's concentration) and on an interaction between industry- and firm-level determinants such as economies of scale, product differentiation and entry and exit barriers (Feeny et al, 2005; Slater and Olson, 2002).

The strategic management literature focuses on organizational structures and management practices as the main source of heterogeneity in performance between firms (Teece, 1981; Barney, 2001). These include tangible (financial and physical factors of production) as well as

[2] A popular extension of this definition is to adjust the value of total sales by the net value of stock and inventories at the end of the year. As in this case the number of observations available would drop substantially, we decided not to perform this adjustment.

intangible assets (technology, age as a proxy for accumulated knowledge which arises from learning-by-doing effects).

We capture these potential determinants through a mix of industry effects and individual firm level variables. The former would capture all the effects that industry structure has on firms' profitability. On the other hand, firms' characteristics, including the age of the firm, the value of its equipment, the number of its workers, its ownership (foreign vs. domestic), its presence in foreign markets and whether it has a ISO9000 certification should take into account a large part of the other potential determinants (see the Appendix for a complete description of the variables used).

3. Empirical implementation

In order to test for the effects of e on π we pool all the countries together and write a simple specification of productivity determination:

$$\pi_{fcit} = \alpha_c + \sum_{c=1}^{n} \beta_c d_{fc} e_{ft} + \Gamma X_{ft} + \mathrm{K} Z_f + \lambda_i + \gamma_t + \varepsilon_{ft} \qquad (1)$$

where f is firm, c is country, i is industry and t is time; α is country effects, d_{fc} is a dummy that take the value 1 if firm f is in country c, X and Z are vectors of controls specific to the firm which are time variant and time invariant respectively, λ are industry effects and γ is time dummies. This specification is very close to running regressions separately by countries except that the effects of the control variables (and of the time and industry dummies) are not allowed to vary by country. As noted above, this specification allows controlling for a number of potential profitability determinants at the firm, country as well as at the industry level. However, industry and country level dynamics affecting profitability could vary over time. For example, country specific or industry specific shocks could influence firms' productivity (and thus their profitability). In order to control for those factors, we modify specification (1) by including country-year and industry-year effects:

$$\pi_{fcit} = \alpha_{ct} + \sum_{c=1}^{n} \beta_c d_{fc} e_{ft} + \Gamma X_{ft} + \mathrm{K} Z_f + \lambda_{it} + \varepsilon_{ft} \qquad (1')$$

We also use a parsimonious version of this specification without the control variables in X and Z in order to maximize the number of observations available for the estimation.

While specification (1’) controls for a large number of possible productivity determinants, the *β* estimates may be biased due to the endogeneity of the energy efficiency variable. There are two main possible sources of endogeneity in this case. The first and possibly the most important one is due to omitted variables: unobservable firms’ characteristics may drive both the energy efficiency as well as the profitability of firm. For example, the ability of the firm’s management could influence the decision of the firm to adopt energy savings technologies and at the same time would have a clear impact on its profitability. There are many of such factors that could be influencing both variables, some of which (as the management ability) are inherently unobservable and some of which are potentially observable (e.g. the level of skills of the firm’s labour force) but in practice are not available in the dataset we are using. Failing to control for such factors is likely to bias the *β* coefficients in (1’). In order to tackle this problem, we estimate (1’) through fixed effect estimation:

$$\pi_{fcit} = \rho_f + \alpha_{ct} + \sum_{c=1}^{n} \beta_c d_{fc} e_{ft} + \Gamma X_{ft} + \lambda_{it} + \varepsilon_{ft} \qquad (2)$$

where ρ are firm level effects (note that the time invariant firms’ characteristics in Z included in (1’) have now been wiped out by the fixed effects). Although this addition should greatly reduce the omitted variable bias, some bias may still be present to the extent that some time varying firms’ characteristics drive both *π* and *e*. While this may be the case, the fact that our dataset spans only three years reduces the possibility of large changes in unobservable firms’ characteristics over time (e.g., type of management, ownership structure, markets, etc.). Through FE estimation we effectively use the difference between the observed value of the variables and the average value for each firm over the 3 years - i.e., the within group mean (Baltagi, 2005).

The other potential source of endogeneity is reverse causality. To the extent that profitability influences the choice of the production technology to be used, this may again produce inconsistent estimates. However, this problem appears to be less biting than the omitted variable in this instance. In fact, the contemporaneous specification in (1) allows minimizing the feedback effect from profitability to energy efficiency, as the decision to change technology is made in earlier periods (and thus it may be influenced by the firm’s performance in previous years). Notwithstanding this, and in the absence of variables to be used as suitable instruments to implement IV estimation, we make an effort to address one important channel through which profitability may affect energy efficiency. That is done by controlling for the value of the firm’s retained earnings lagged one year which may have influenced the adoption of energy efficient technology. As this data is widely available only for a handful of countries in the dataset (i.e. Bangladesh, Philippines, Morocco and Zambia), we run this specification at the country level:

$$\pi_{fit} = \rho_f + \beta e_{ft} + \varphi y_{t-1} + \Gamma X_{ft} + \lambda_{it} + \varepsilon_{ft} \qquad (3)$$

where y is retained earnings.

4. Results

Table 1 present the results of running specifications (1') and (2). In column (1) we employ a parsimonious version of (1') using no firm level controls. The results are fairly mixed: almost half of the countries (13) have a statistically significant negative coefficient, in line with the hypothesis that higher energy efficiency (i.e., lower energy intensity of production) is also associated with higher productivity.[3] However, for eight countries the β coefficients are positive, while for the rest the coefficients are not significantly different from zero. Adding some of the firm-level controls, including age, number of workers and dummies for being an exporter and for being foreign owned does not affect much the results (column 2). The only instances in which the coefficients change radically are those countries – i.e., Mali and Morocco – where the sample size is considerably reduced due to the additional controls. Thus, the β coefficients appear to be highly robust to the inclusion of these extra controls. All of these controls have the expected positive (and significant) sign. Again, the results appear to be robust to the inclusion of other firm level characteristics (column 3), i.e., the value of the firm's equipment and the dummy for the ISO9000 certification, which substantially reduce or entirely eliminate the number of observations in many countries (the total number of observations is half of that in column 2). For those countries for which the observations available is unaltered (e.g., Brazil, Ethiopia, Honduras, Viet Nam), the beta coefficients are not much affected relative to column (2).

[3] A negative coefficient is considered significantly different from zero if adding (the absolute value of) its associated standard error to it returns a negative value. The reverse procedure is applied for the positive coefficients.

Table 12 Profitability and energy efficiency

	(1)		(2)	(3)	(4)		(5)
	Coeff	**SE**	**Coeff**	**Coeff**	**Coeff**	**SE**	**Coeff**
Bangladesh	0.59***	(0.14)	0.72***		-0.13	(0.14)	-0.19
Benin	-0.17	(0.17)	-0.10		-0.80	(0.60)	
Brazil	-0.54***	(0.10)	-0.51***	-0.51***	-0.41***	(0.11)	-0.40***
China	0.11	(0.20)	0.12		-0.64***	(0.25)	
El Salvador	0.08	(0.15)	0.15	0.15	0.12	(0.16)	0.11
Eritrea	-1.91**	(0.75)	-2.18**	-2.91***	-3.50***	(1.35)	-2.62
Ethiopia	-0.40**	(0.19)	-0.34*	-0.35*	-0.48	(0.32)	-0.70
Guatemala	-0.15	(0.10)	-0.15	-0.15	-0.77***	(0.21)	-0.83***
Honduras	-0.22*	(0.12)	-0.25*	-0.24*	-0.28**	(0.12)	-0.27**
India (2000)	0.08	(0.10)	0.00		-0.24	(0.27)	0.08
India (2002)	-0.20***	(0.07)	-0.20***		-0.27*	(0.14)	-0.11
Indonesia	-0.00	(0.06)	0.01		-0.43***	(0.13)	
Kenya	0.37***	(0.10)	0.42***		-0.11	(0.09)	
Madagascar	-1.53***	(0.19)	-1.50***	-0.83**	-2.67***	(0.99)	-1.78
Malawi	-0.42**	(0.17)	-0.38**	-0.40**	-0.98**	(0.41)	-0.99**
Mali	-0.22	(0.50)	0.65*		-0.53	(0.60)	
Mauritius	-0.30***	(0.10)	-0.28***	-0.34***	0.02	(0.12)	0.05
Morocco	-0.23**	(0.09)	0.00		-0.51**	(0.21)	-0.43**
Mozambique	-0.25	(0.16)	-0.17		-0.75	(1.19)	
Nicaragua	-0.01	(0.12)	-0.03	-0.04	-1.60***	(0.30)	-1.56***
Pakistan	0.08*	(0.04)	-0.22	-0.14	-0.11***	(0.04)	0.00
Philippines	0.41***	(0.09)	0.44***	0.45***	-0.35*	(0.18)	-0.37*
Senegal	-0.87***	(0.22)	-0.81***		-1.24***	(0.21)	
South Africa	0.19	(0.31)	0.27	0.39	-3.41***	(1.18)	-3.57**
Sri Lanka	-0.35***	(0.11)	-0.38***		-0.51*	(0.29)	
Tanzania	0.27*	(0.16)	0.13	0.51	0.07	(0.08)	-0.02
Thailand	0.31***	(0.07)	0.34***	0.16	-0.26	(0.27)	0.05
Uganda	0.39***	(0.09)	0.40***		-0.01	(0.12)	
Viet Nam	0.79***	(0.08)	0.81***	0.84***	-0.14	(0.11)	-0.21
Zambia	0.10	(0.34)	0.02	-0.03	-1.19	(0.74)	-1.15
Age (ln)			0.01***	0.01***			
Workers (ln)			0.01***	-0.00			-0.02
Equipm (ln)				0.01***			-0.01*
Exporter			0.01***	0.02***			
Foreign			0.02***	0.02***			
ISO				0.01			
Work sq (ln)							0.00
Eq. sq. (ln)							0.003*
Fixed eff.							
Industry-year	YES		YES	YES	YES		YES
country-year	YES		YES	YES	YES		YES
Firms	NO		NO	NO	YES		YES
Observations	40781		31635	15296	40781		24523
Adj. R-sq.	0.093		0.101	0.088	0.754		0.749

Notes: Robust standard errors in parentheses; * significant at 10%; ** significant at 5%; *** significant at 1%. Dependent variable is value added net of labour costs over total sales value. The value for each country indicates the value of the coefficient of energy intensity in the different specifications.

On the other hand, results change substantially when adding firm's fixed effects in column (4). Only two coefficients are now positive, while for 27 countries they are negative and for 13 countries the coefficients are not significantly different from zero (5 percent level). For all countries but three (El Salvador, Brazil and Mauritius), the beta coefficients in column (4) are more negative than in column (1), which has the same sample size of column (4). However, the coefficient is only significantly more negative after the inclusion of firms' effects for Mauritius. In column (5) we add the two time varying firm level controls, i.e., the total number of permanent workers and the value of equipment. Again, the coefficients are robust to this inclusion as long as the sample size does not shrink significantly. For example the countries with the highest share of valid observations over the total sample (see Table A2 in Appendix), i.e., Morocco, Brazil, Viet Nam, Philippines and Zambia, do not experience a substantial change in the beta coefficients from column (4) to (5). Likewise, major changes in the coefficients are observed only for those countries whose number of observations drops significantly from column 4 to column 5 (i.e., Pakistan, Thailand, Madagascar, Eritrea). Once we keep the same sample in column (4) as in column (5) the beta coefficients are virtually unchanged even in these countries (not shown here). This is a further confirmation that the results are in fact robust to the inclusion of the other controls in column (5).

We also test the robustness of the results to a possible reverse causality channel, by running country-level regressions of the type of (3) which includes the value of retained earnings lagged one year. The addition of this term reduces substantially the number of observations as it excludes one year (out of the three available) and as several countries have only a few firms reporting data on this variable. We run this specification for the four countries with the largest (relative) coverage of this variable, i.e., Bangladesh, Philippines, Morocco and Zambia. These turn out to be the only countries which in this case have a number of valid observations larger than two third of the total sample. The results are reported in Table 2, where for each country there are two columns reporting the results of two different specifications using the same sample: without (the odd columns) and with (the even columns) the lagged retained earnings variable. As it is clear from the Table, none of the energy intensity coefficients is affected by the inclusion of this further control, except in the case of Zambia, where the coefficient becomes more negative. Therefore according to this test the possible bias caused from reverse causality does not seem to be important, and if anything it may bias the absolute magnitude of the energy coefficient downwards. Note that the energy coefficients are not significant at the standard level mainly due to the exclusion of one year of observations which reduces considerably the sample size.

Table 13 **Profitability and energy efficiency, robustness by country**

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Bangladesh		**Philippines**		**Morocco**		**Zambia**	
Energy intensity	-0.368	-0.376	0.038	0.040	-0.413	-0.414	-0.133	-0.374
	(0.321)	(0.316)	(0.143)	(0.143)	(0.353)	(0.354)	(0.428)	(0.487)
Workers (ln)	-0.033***	-0.033***	-0.036	-0.036	0.011	0.011	-0.049	-0.063
	(0.012)	(0.012)	(0.031)	(0.031)	(0.047)	(0.047)	(0.076)	(0.076)
Equip. (ln)	-0.071***	-0.072***	-0.113*	-0.115*	0.324*	0.323	0.056	0.013
	(0.027)	(0.026)	(0.065)	(0.065)	(0.195)	(0.196)	(0.082)	(0.094)
Equip. sq. (ln)	0.004***	0.004***	0.004	0.004	-0.020	-0.020	0.000	0.002
	(0.001)	(0.001)	(0.003)	(0.003)	(0.013)	(0.013)	(0.004)	(0.004)
Retained $earn_{,t-1}$ (ln)		-0.004		-0.005		0.002		0.019
		(0.004)		(0.010)		(0.007)		(0.016)
Obs.	1441	1441	872	872	931	931	224	224
Adj. R-sq.	0.896	0.896	0.885	0.885	0.555	0.554	0.888	0.888

Notes: Robust standard errors in parentheses; * significant at 10%; ** significant at 5%; *** significant at 1%. Dependent variable is value added net of labour costs over total sales value. All specifications include industry-year and firms' fixed effects.

Finally it is worth exploring how the relationship between profitability and energy efficiency varies across industries as well. In order to do so we run the firms' fixed effects regression of the type of (2) by industry. The dataset contains 24 industries which have enough data to meaningfully explore this relationship. As shown in Table 3, twenty out of these twenty-four industries (comprising over 95 percent of the firms in the dataset) have negative energy intensity coefficients, half of which are significant at least at the 10 percent level. On the other hand, in four industries the coefficients are positive but in all of these cases it is not significantly different from zero. These results confirm the previous evidence that even across industries there is a positive relationship for firms between becoming more energy efficient and increasing the profitability. This is particularly true for a number of large sectors in developing countries, such as textiles, garments, food, wood and furniture, but the finding also applies to more 'sophisticated' sectors such as chemicals and pharmaceuticals and IT services (which has one of the highest coefficients in the sample). On the other hand, the effect is negligible in other important sectors for developing countries, such as agro-industry and construction.

Table 14 **Profitability and energy efficiency, regressions by industry**

	Coeff.	S.E.	Obs	Firms	R-sq.
Textiles	-0.221***	(0.070)	5267	2016	0.023
Leather	-0.229*	(0.125)	1612	621	0.041
Garments	-0.190**	(0.078)	7242	2793	0.029
Agro-industry	-0.042	(0.123)	816	352	0.069
Food	-0.261***	(0.092)	5300	2080	0.042
Beverages	-0.281***	(0.049)	226	105	0.208
Metals and machinery	-0.257	(0.214)	3652	1455	0.082
Electronics	-0.063	(0.105)	3336	1253	0.012
Chemicals and pharmaceutics	-0.294**	(0.139)	3089	1339	0.044
Construction	-0.477	(0.831)	218	92	0.145
Wood and furniture	-0.485**	(0.217)	3603	1454	0.056
Non-metallic & plastic mater.	-0.211*	(0.117)	2228	907	0.074
Paper	-1.206	(0.863)	481	189	0.127
Sport goods	-5.799	(3.788)	129	44	0.224
IT services	-2.164**	(0.917)	301	120	0.099
Other manufacturing	0.053	(0.412)	758	301	0.047
Telecommunications	-0.918	(1.276)	99	35	0.018
Accounting and finance	0.143	(1.278)	64	26	0.162
Advertising and marketing	-0.117	(0.556)	95	39	0.016
Other services	-0.872***	(0.224)	180	64	0.624
Mining and quarrying	-0.194	(0.203)	47	18	0.089
Auto and auto components	-1.011	(0.731)	1950	708	0.042
Other transport equipment	0.028	(1.499)	45	17	0.123
Other industries	0.274	(0.160)	33	11	0.041

Notes: Robust standard errors in parentheses; * significant at 10%; ** significant at 5%; *** significant at 1%. Dependent variable is value added net of labour costs over total sales value. All regressions include firms and country-year fixed effects. The coeff. column indicates the value of the energy intensity coefficient of the industry

5. Discussion

Two clear messages emerge from these results. First, if one adequately controls for the major factors potentially biasing the beta coefficients, it turns out that higher energy efficiency is systematically associated with higher profitability in the vast majority of developing countries in the sample. This is a powerful confirmation of the hypothesis that there seems to be no trade-off between the adoption of energy saving technologies and profitability even in those countries characterized by the lowest rates of adoption. Second, unobservable firm characteristics tend to bias upwards the relationship between energy intensity and profitability, at least in the sample of developing countries considered. In other words, on average these unobservable factors tend to be correlated with both energy intensity and profitability in the same way (i.e. positively or negatively). Therefore failure to control for these factors produces more positive beta coefficients than the true coefficients. The substantial effect of these firm level factors on the beta coefficients is not surprising when considering the large jump in the adjusted R-squared when adding the firms' fixed effects (cf. column (1) and column (4)). To the best of our knowledge this is the first time the importance of unobserved firms' level characteristic in driving the relationship between profitability and energy efficiency is documented for a large set of developing countries, and should deserve further investigation.

These results point to a fairly large heterogeneity in the power of this (almost invariably positive) relationship between energy efficiency and profitability across countries and industries. Understanding the determinants of such heterogeneity is beyond the scope of the present analysis, but it would be important to unpick some of the country and industry characteristics that help translate higher energy efficiency into higher profitability. This area should be high up in the energy efficiency research agenda.

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Appendix

Data cleaning and countries' selection

Firms usually report energy consumption in the c274e question of the World Bank survey. However for certain countries the coverage of the electricity consumption (excluding fuels) - i.e., question code c274f - is wider than that of energy consumption. As the overall correlation between the two questions is extremely high (i.e. 0.97), we replace energy consumption with electricity consumption in those countries where the coverage of the latter is larger than the former. This modification allows us to extend to sample size while not compromising on the reliability of the data (energy consumption data for all firms in one country are homogeneously defined).

We exclude all of those countries which have neither energy nor electricity data. We then calculate profitability and energy intensity as defined in the main text. To minimize the problem of misreported data, we exclude those firms for which energy intensity values are large than 2 (i.e., energy consumption more than twice as large as total sales). We also exclude firms for which profitability is lower than -0.5 or higher than 0.95. We perform the same exercise for each of the three years before the survey and then exclude those countries for which the total number of valid observations is less than 35 percent of the total sample. This leaves us with the 29 countries (with India included in two separate years) subject of the analysis.

Table A1 Variables' description

Variables	Variable name	Units	Question Code
Total value of sales	sales	In 000 LCU	c274a
Manpower cost	labour	In 000 LCU	c274j
Energy	energy	In 000 LCU	c274e
Raw material cost (excl. fuels)	materials	In 000 LCU	c274b1y
Number of workers	worker	Number	c262a1y
Capital	equipment	In '000	C281a1y
industry	λ	Dummy variable	Industry
Age of firm	age	Years	surveyyear-c201
Exporting firm	Export	Dummy variable	exporter
Foreign owned	Foreign	Dummy variable	(ownership==1)
ISO9000 certification	ISO	Dummy variable	C257

Source: World Bank enterprise surveys, various years.

Table A2 Observations available in Table 1, by country

	Potential obs.	Obs. col. 1 & 4	Obs. col. 5
Bangladesh	3,003	2,705	1,791
Benin	591	458	0
Brazil	4,926	4,392	4,262
China	4,644	3,077	0
El Salvador	1,395	709	686
Eritrea	237	134	40
Ethiopia	1,281	956	818
Guatemala	1,365	680	655
Honduras	1,350	700	627
India (2000)	2,685	1,074	735
India (2002)	5,481	3,582	2,350
Indonesia	2,139	1,687	0
Kenya	852	438	0
Madagascar	879	334	204
Malawi	480	276	255
Mali	465	244	0
Mauritius	636	279	181
Morocco	2,550	2,362	2,292
Mozambique	582	261	0
Nicaragua	1,356	825	757
Pakistan	2,895	2,669	885
Philippines	2,148	1,791	1,728
Senegal	786	335	0
South Africa	1,809	1,251	1,143
Sri Lanka	1,356	1,025	0
Tanzania	828	425	306
Thailand	4,155	4,109	1,508
Uganda	900	414	0
Viet Nam	3,450	3,135	2,852
Zambia	621	454	448

Source: Authors' elaboration on World Bank enterprise surveys, various years.

IV. A decomposition analysis of energy intensity for developing countries

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Abstract

Recent Copenhagen climate change negotiations emphasize the role of energy efficiency as a key factor to reduce greenhouse gas emissions by boosting profits for firms and growth for countries. Energy efficiency is particularly relevant for the poorest regions that seek emissions reduction strategies preserving development targets. In this paper we investigate the path of energy intensity in 20 developing countries and we analyse the components of energy intensity variations. By using the Fisher Ideal Index energy intensity decomposition technique we will assess the role of energy efficiency and economic structural components in determining the energy intensity. Results show improved energy efficiency and a decreasing energy intensity path for the majority of countries but heterogeneity of results and the limited time horizon of investigation do not support unambiguous policy implications.

1. Introduction

Global warming emergency imposed a long debate on the best policies to reduce greenhouse gas emissions with cost effective tools. Energy efficiency is one of the most interesting issues analysed by economists and policy makers within the climate change debate. Whereas a McKinsey Report (Farell and Remes 2009) stresses that there are opportunities for firms to improve energy efficiency by increasing profits, the recent World Development Report (2010) points out that to reach ambitious emissions reduction targets, developing countries should be funded by rich countries through appropriate financial transfers. As shown by the recent Copenhagen negotiations a key priority is to find agreements designed to involve developing countries in mitigation policies and, with this purpose, a careful analysis is needed to investigate in depth the path of energy efficiency and to identify those countries where effective policies are needed to improve energy efficiency over time.

In this paper we consider a panel of 20 countries and we will investigate the path of energy intensity in manufacturing sectors over time. Moreover, we will assess to what extent movements of the energy intensity index depend on structural shifts of the economy (the extent economy propels production towards “dirty”/”green” sectors) or energy efficiency (interpreted here as the energy consumption for each unit of value added production) through the Fisher Ideal Index decomposition technique. At the best of our knowledge this paper represents the first attempt to apply this index to data covering a wide panel of developing countries.

As outlined by Ang and Zhang (2000) many techniques have been adopted by the previous published literature such as the Laspeyres index Method or the Arithmetic Mean Divisia Method. The authors stress that these techniques allow decomposing energy intensity shifts in a “structural component” and an “energy efficiency” component, but they provide a residual component whose interpretation is complex. To solve the residuality problem Ang and Liu (2001) and Ang (2005) propose the LMDI technique whereas Boyd and Roop (2004) introduce the Fisher Ideal Index technique. In this paper we use the Fisher Ideal Index technique because it is quite intuitive from a conceptual point of view as it is founded on the Laspeyres and Paasche Indices that are usually introduced in the microeconomics textbooks consumer theory chapters.

As stressed by Hoekstra and van Den Bergh (2003), a reliable decomposition technique should be robust to completeness, time reversal and zero value tests. The completeness test evaluates whether a decomposition technique has a residual component. The zero value robustness test assesses how the method performs when there are zero values in the data set used to calculate the index. The time reversal test, as first proposed by Fisher requires that if the time sequence between the first and last year being analysed is reversed, the new index should be the reciprocal of the original. The Fisher Ideal Index is robust to all three tests, whereas the LMDI index presents computational problems with 0 values that can be handled by replacing 0 with small positive values.

As outlined by Cahill et al. (2009), another source of decomposition techniques distortions may come from the use of value added to calculate energy intensity. Changes in value added may be unrelated to production output and measures of energy intensity based on physical output rather than on value added have been proposed such as ODEX. However, as shown by Cahill et al. (2009), the ODEX technique fails to satisfy the time reversal technique and has not documented approach to handle zero values.

Next paragraph will describe more in depth data and the adopted methodology. Section 3 will describe the results, and finally, we will draw our conclusions.

2. Data and methodology

We use the INDSTAT2009 Rev 3 dataset for value added and the IEA Energy Balance for energy consumption. INDSTAT covers 23 divisions, IEA dataset covers 11 sectors aggregating INDSTAT 23 divisions[4].

- We investigate 20 countries[5]. The choice of countries is based on the following criteria:
- We select among a list of countries indicated as "developing" by the IMF.
- We select countries that are covered contextually by IEA and INDSTAT data.
- We select those countries for which data are available in both the IEA and INDSTAT dataset for at least 5 years.
- We select those countries for which data are available for at least 5 out of 11 IEA macro-sectors. As our analysis also includes structural composition we choose those countries for which this component is relevant.
- We then "clean data" by eliminating from the dataset sectors of countries for which we find inconsistencies (e.g., 0 for value added in X sector and a positive value for energy consumption and vice versa) and outliers[6]. We also exclude for each country those sectors for which data are temporally inconsistent (e.g., / 0 value for te periods 0...t-1 and a positive value at the time t).

The first step is to calculate energy intensity for each country as ratio between energy consumption (expressed as kilo tons of oil equivalent) and value added. Value added are taken in local currency units from INDSTAT, adjusted according to the IMF GDP deflator to 2006 levels and then transformed to 2006 PPP international dollars. Energy intensity is thus expressed as ktoe/ 2006 PPP international dollars for each country.

After the calculation of energy intensity for each country we apply the Fisher Ideal Index Technique. This technique is based on the Laspeyres and Paasche Indices. The Laspeyres index can be expressed as follows:

$$L_{str} = \sum_i S_{i,T} I_{i,0} / \sum_i S_{i,0} I_{i,0}$$

[4] Consistency between the INDSTAT data and IEA data is showed in the Appendix 1.
[5] See appendix 2.
[6] Dataset of value added is included in the Appendix 3 and dataset of energy balance is included in the Appendix 4.

$$L_{eff} = \sum_i S_{i,0} I_{i,T} / \sum_i S_{i,0} I_{i,0}$$

Where L_{str} is the Laspeyres structural effect, and L_{eff} is the Laspeyres energy efficiency, S is the share of sector i in total value added in time t and I is energy intensity of sector i in time t. The Paasche index can be expressed as follows

$$P_{str} = \sum_i S_{i,T} I_{i,T} / \sum_i S_{i,0} I_{i,T}$$

$$P_{eff} = \sum_i S_{i,T} I_{i,T} / \sum_i S_{i,T} I_{i,0}$$

Where P_{str} is the Paasche structural effect and P_{eff} is the Paasche energy efficiency component. The overall Fisher Ideal Index can be calculated as follows:

$$FII = (L_{str} P_{str})^{1/2} * (L_{eff} P_{eff})^{1/2}$$

Where the Fisher structural effect is $(L_{str} P_{str})^{1/2}$ and the Fisher energy efficiency effect is $(L_{eff} P_{eff})^{1/2}$. The Fisher Ideal Index is a multiplicative energy intensity index as the ratio between the levels of energy intensity in a country in two different periods t and t+1 can be calculated by multiplying the Fisher Ideal Index structural and energy efficiency effects. In other words, if in the period t+1 energy intensity is 20 percent higher than in the period t the Fisher Ideal Index is 1.20 and by multiplying the Fisher Ideal Index structural and energy efficiency components the result will be 1.2. Energy efficiency and the structural component are lower (higher) than the ones in the first periods when their value is $< (>) 1$. The interpretation is tricky: when the energy efficiency component is < 1 (> 1) the consumption of energy per unit of value added (being constant over time the structural composition of the economy) reduces (increases) and energy efficiency improves (worsens). Analogous interpretation can be attributed to the structural component of energy intensity. The following section summarizes the results.

3. Results

From the analysis of the results we can extract some interesting findings:

1) Energy intensity is very heterogeneous across countries and sectors. If we look at the table contained in Appendix 5, energy intensity varies from a minimum value of 0.01 in Chile to 1.78 in Albania.
2) 13 out of 20 countries show a negative trend of energy intensity (expressed by a value of the Fisher Ideal Index < 1 in the last year of analysis), but we do not find robust evidence that the path of energy intensity will be decreasing over time for developing countries (see Appendix 6).
3) The energy intensity component depending on energy efficiency shows a negative trend (expressed by a value of the energy efficiency component < 1 in the last year observation) for 14 out of 20 countries (see Appendix 6 and 7).
4) The structural component is > 1 for 14 out of 20 countries in the last year of observation (see Appendix 6).

In spite of the limits deriving from the time dimension data availability, IEA and UNIDO dataset consistency problems and the restricted panel of countries that we use for our analysis data shows a tension between the structural and the energy efficient components of energy intensity over time. Whereas during the growth path developing countries tend to grow in “dirty” sectors by worsening the structural component of energy intensity, on the other hand growth improves technical efficiency. However, we stress that for some countries the structural and the energy efficiency effect follow the same direction over time (e.g., in Latvia both the structural and the energy efficiency effect worsen, whereas in Bulgaria they improve).

The fact that the majority of countries show a negative trend of energy intensity over time suggests that the energy efficiency effect in many cases dominates the structural effect. This study would confirm findings of other decomposition studies in the environmental economics literature pointing out that the energy efficiency effect is more intense than the structural effect (Stern 2002), but of course the limited time dimension of our sample imposes a cautious interpretation of results.

4. Conclusions

In this paper we drive a decomposition analysis study for a sample of 20 developing countries to discriminate shifts of energy intensity depending on the change of the structural economies composition from those depending on energy efficiency. Data supports the finding that many developing countries tend to concentrate their growth path towards dirty sectors, but on the other side the energy technical efficiency improves over time. In many cases the energy efficiency effect dominates the structural effect. A wide heterogeneity of results across countries weakens the robustness of the above mentioned conclusions and calls for further research in the field.

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Appendix 1. Consistency between the IEA Energy Balance dataset and the INDSTAT 2009 Rev 3 dataset.

IEA data	INDSTAT ISIC division
Iron and steel	Group 271 and class 2731
Chemical and petrochemical	Division 24
Non-ferrous metals	Group 272 and class 2732
Non-metallic minerals	Division 26
Transport equipment	Divisions 34 and 35
Machinery	Divisions 28, 29, 30, 31, 32
Food and tobacco	Divisions 15 and 16
Paper, pulp and printing	Divisions 21 and 22
Wood and wood products	Division 20
Textile and leather	Division s 17, 18 and 19
Non-specified industry	Divisions 25, 33, 36, 37

Appendix 2. List of countries.

Albania	Indonesia
Azerbaijan	Latvia
Argentina	Lithuania
Brazil	Macedonia
Bulgaria	Republic of Moldova
Chile	Morocco
Colombia	Philippines
Estonia	Romania
Georgia	Russian Federation
India	South Africa

Appendix 3. Available data for value added per sector and per country (2006 international millions of PPP $ from INDSTAT)

Albania	2000	2001	2002	2003	2004	2005	2006
Chemical and petrochemical	12	9	19	15	20	64	97
Food and tobacco	54	53	57	69	73	98	93
Iron and steel	27	33	45	38	63	54	82
Non metallic minerals	47	44	48	59	56	59	86
Non specified industry	11	14	14	17	16	25	26
Paper pulp and printing	11	21	17	14	25	23	23
Textile and leather	72	88	120	125	117	118	125

Argentina	1995	1996	1997	1998	1999	2000	2001	2002
Food and tobacco	12491	12398	11956	10754	10940	9887	10403	12826
Iron and steel	1281	1426	1779	1641	1042	1295	1466	3092
Non ferrous metals	252	212	318	189	234	348	295	877
Non metallic minerals	1558	1776	1865	1702	1544	1353	1249	979
Non specified industry	1994	2060	2659	2868	2420	2296	1988	2202
Paper pulp and printing	2993	2828	3730	3916	3251	3225	3175	2868
Textile and leather	2942	3004	3754	3368	3090	2742	2514	2334
Transport equipment	2212	2600	3095	2762	1632	1781	1544	2089
Wood	265	282	385	428	367	342	295	297

Azerbaijan	2001	2002	2003	2004	2005	2006
Chemical and petrochemical	59	83	78	99	158	137
Food and tobacco	402	496	679	682	611	483
Iron and steel	11	32	51	96	95	81
Machinery	61	67	120	132	97	152
Non ferrous metals	8	8	60	99	107	128
Paper pulp and printing	10	16	21	20	15	29
Textile and leather	31	29	29	27	25	44

Brazil	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Chemical and petrochemical	26994	26684	26994	32023	31176	31741	32768	35016	37899	34778
Food and tobacco	43578	44444	43578	42830	41939	49240	50922	55187	56287	58708
Iron and steel	8524	8917	8524	9237	11374	11645	14537	16461	23424	20845
Non-ferrous metals	2772	3225	2772	4294	4742	4740	4930	5258	6377	4969
Non-metallic minerals	7461	8000	7461	8769	10063	10778	11366	11191	11055	9910
Non-specified industry	15583	15861	15583	15872	17886	16877	17464	19699	19608	19889
Paper pulp and printing	18855	18898	18855	19189	22550	21069	22462	22920	22932	20827
Textile and leather	17058	15033	17058	16384	17387	17723	17793	17743	18656	17012

Bulgaria	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Chemical and petrochemical	1634	1139	576	550	704	634	597	602	553	629	656
Food and tobacco	2367	1881	1457	1352	1205	1040	973	1179	1285	1519	1514
Iron and steel	647	659	264	59	366	145	123	244	537	332	355
Machinery	1800	1665	1401	1198	1087	1142	1198	1340	1440	1773	1882
Non-ferrous metals	445	376	156	146	233	107	32	86	185	374	624
Non-metallic minerals	444	382	334	324	283	343	372	422	556	685	918
Non-specified industry	532	432	353	336	316	320	362	470	461	550	703
Paper pulp and printing	334	285	246	254	265	255	290	340	380	425	461
Textile and leather	1202	1050	854	815	844	961	1062	1221	1336	1303	1234
Transport equipment	463	333	275	157	142	51	128	132	176	208	236
Wood and wood products	116	98	83	104	82	76	86	118	185	193	211

Chile	2001	2002	2003	2004	2005	2006
Chemical and petrochemical	5940	6575	8840	8699	12587	9189
Iron and steel	1053	827	1138	1388	987	976
Non-metallic minerals	1695	1447	1373	1429	1432	1530
Non-specified industry	1585	1763	1618	1571	1612	1538
Paper pulp and printing	3767	3535	3277	3457	3229	3206

Colombia	2000	2001	2002	2003	2004	2005
Chemical and petrochemical	5201	5260	5464	5709	5502	5369
Food and tobacco	9755	10146	10780	10484	10646	11013
Iron and steel	1050	956	1099	1637	2294	2275
Machinery	1906	1912	1995	2027	2188	2477
Non-metallic minerals	2427	2565	2747	3044	2972	2542
Non specified industry	2249	2470	2565	2665	2719	2952
Paper pulp and printing	2728	2781	2923	2995	3038	3048
Textile and leather	3479	3503	3449	3525	3662	3653
Wood and wood products	162	149	158	160	184	181

Estonia	2000	2001	2002	2003	2004	2005	2006
Chemical and petrochemical	82	97	92	104	115	143	138
Food and tobacco	335	342	341	359	341	367	273
Machinery	320	284	290	419	462	546	270
Non-metallic minerals	130	135	149	170	205	238	297
Non-specified industry	257	292	317	350	361	379	415
Paper pulp and printing	158	174	206	204	208	220	253
Textile and leather	290	305	324	312	338	166	150
Transport equipment	49	47	56	106	94	119	71
Wood and wood products	223	250	330	359	399	405	472

Georgia	2001	2002	2003	2004	2005	2006
Chemical and petrochemical	18	24	22	42	63	89
Food and tobacco	143	137	157	231	205	220
Iron and steel	22	10	20	6	29	27
Machinery	15	9	10	15	26	29
Non-metallic minerals	24	4	17	11	13	66
Non-specified industry	8	8	5	11	15	25
Paper pulp and printing	15	15	14	23	26	35
Textile and leather	4	4	3	5	8	10
Transport equipment	30	30	40	16	7	13

India	1998	1999	2000	2001	2002	2003	2004
Chemical and petrochemical	33314	35370	29775	28174	30282	31436	34413
Food and tobacco	17752	19502	18542	18331	18709	17828	18744
Iron and steel	15051	14555	11553	9896	15142	20627	32470
Machinery	22807	22278	21376	21315	21897	23611	25762
Non-ferrous metals	3071	4638	3551	3423	3613	4209	6769
Non-metallic minerals	5861	8047	7899	7952	7453	7727	10348
Non specified industry	7552	9971	7770	9327	8893	9738	10972
Paper pulp and printing	4031	4796	6026	4845	5707	5628	5446
Textile and leather	16521	17297	17677	15204	16472	16584	17967

Indonesia	1999	2000	2001	2002	2003	2004	2005
Chemical and petrochemical	8758	9340	9670	8284	10253	8144	10776
Food and tobacco	15134	15965	18465	18137	23228	22480	24572
Iron and steel	1795	2058	3505	3050	2556	2361	2373
Machinery	8317	12970	11923	9154	9068	10252	10298
Non-ferrous metals	1354	1256	1122	617	848	857	1114
Non-specified industry	6195	6380	6569	5526	5932	8208	7629
Paper pulp and printing	4742	5814	5929	5646	5730	5864	7236
Textile and leather	15050	14834	11107	13401	13529	12781	11349

Latvia	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Chemical and petrochemical	199	201	173	267	114	84	76	84	77	95	102	127	138
Food and tobacco	2534	2025	1789	1341	1042	795	612	556	726	626	565	609	690
Machinery	894	668	563	586	485	216	240	222	239	317	342	397	668
Non-metallic minerals	243	144	115	95	147	82	65	88	81	98	142	163	144
Non-specified industry	462	302	222	203	221	167	177	168	193	237	288	316	302
Paper pulp and printing	265	294	294	278	307	218	229	209	218	247	237	259	294
Textile and leather	715	473	527	520	492	311	254	273	255	266	228	247	473
Transport equipment	557	401	248	177	163	88	79	100	90	89	94	106	401
Wood and wood products	529	493	417	639	721	447	240	467	514	560	584	671	493

Lithuania	2001	2002	2003	2004	2005	2006
Chemical and petrochemical	18	28	31	44	65	110
Food and tobacco	183	193	207	271	335	368
Iron and steel	3	4	3	4	4	3
Machinery	90	112	127	190	254	230
Non-metallic minerals	26	34	38	52	68	81
Non-specified industry	63	66	102	156	198	224
Paper pulp and printing	47	53	59	75	86	98
Textile and leather	123	126	140	181	202	204
Transport equipment	139	125	146	176	185	218
Wood and wood products	44	48	65	88	109	127

Macedonia	1997	1998	1999	2000	2001
Chemical and petrochemical	170	166	144	116	131
Food and tobacco	699	631	706	676	624
Iron and steel	214	186	191	233	193
Machinery	148	137	149	146	126
Non-metallic minerals	172	178	198	231	190
Non-specified industry	51	61	76	83	88
Paper pulp and printing	131	127	126	137	126
Textile and leather	342	411	333	321	327
Transport equipment	44	42	39	43	43
Wood and wood products	24	21	22	27	22

Morocco	2000	2001	2002	2003	2004	2005	2006
Chemical and petrochemical	1380	1454	1587	1681	1624	1855	1635
Food and tobacco	3890	3821	4089	3619	3668	4750	4546
Machinery	990	1033	1091	1215	1195	1283	1347
Non-metallic minerals	1124	1099	1228	1229	1083	1235	1305
Non-specified industry	438	451	429	414	413	427	434
Paper pulp and printing	477	480	475	479	473	382	368
Textile and leather	1982	2074	2191	2163	2052	1883	1732

Philippines	1996	1997	1998	1999	2001	2003	2005
Chemical and petrochemical	2923	3103	3411	3441	2620	2196	2249
Food and tobacco	5531	6153	8138	7328	5443	4766	4681
Iron and steel	832	849	815	831	656	466	562
Machinery	4531	5421	7639	8408	8026	6131	7646
Non-metallic minerals	1318	1347	1369	1443	857	957	1127
Non-specified industry	1478	1604	1641	2154	1545	1504	2074
Paper pulp and printing	965	990	1199	1251	919	718	690
Textile and leather	1844	2045	2381	2369	2088	1652	1765

Republic of Moldova	2001	2002	2003	2004	2005	2006
Food and tobacco	616	571	613	571	533	448
Iron and steel	2	1	1	2	5	8
Machinery	61	74	90	80	86	81
Non-metallic minerals	98	121	128	133	129	158
Non-specified industry	39	41	56	72	82	111
Paper pulp and printing	34	40	50	53	59	51
Textile and leather	87	99	117	146	143	179
Wood and wood products	7	10	9	15	21	11

Romania	1990	1992	1994	1996	1998	2000	2001	2002	2003	2004	2005	2006
Chemical and petrochemical	2382	3334	2884	2740	1577	1660	1646	1654	1209	1248	1277	1207
Food and tobacco	10833	8689	1021 8	13573	8458	9606	11079	10260	2968	2929	3222	3363
Iron and steel	1652	1729	2032	2115	1408	1045	1153	1059	1301	2117	1193	1339
Machinery	11122	7173	7379	7677	4876	4401	4903	5164	3938	3984	3705	3790
Non-metallic minerals	3150	2988	2207	2256	1822	1566	1689	1718	1362	1537	1358	1599
Non-specified industry	6723	3364	3271	2961	2235	2535	2795	3107	2173	2343	2308	2329
Paper pulp and printing	1345	812	808	1420	901	1129	1268	1488	941	972	980	953
Textile and leather	11083	5019	5077	5481	3304	3638	4080	4344	4149	4023	3421	3186
Wood and wood products	1345	1188	1358	1819	1031	1273	1355	1503	854	903	740	771

Russian Federation	2001	2002	2003	2004	2005	2006
Chemical and petrochemical	14967	82945	24478	23585	23585	23860
Food and tobacco	34136	35512	39636	40253	40253	45088
Iron and steel	13806	15929	21364	33360	33360	27336
Machinery	33884	32459	27464	29129	29129	29432
Non-ferrous metals	19172	14424	18274	21454	21454	32627
Non-metallic minerals	11618	11850	9803	11508	11508	15794
Non-specified industry	9205	9429	15379	20709	20709	19008
Paper pulp and printing	7952	7596	9474	10147	10147	11832
Textile and leather	3990	4020	4968	6195	6195	5747
Wood and wood products	3372	3747	4534	5395	5395	6884

South Africa	1993	1996	1999	2000	2001	2002	2003	2004	2005	2006
Chemical and petrochemical	3569	4525	2961	3319	3458	3730	3753	3825	4076	4264
Food and tobacco	6470	6508	7632	7869	8070	8633	9102	9601	9861	10842
Iron and steel	2398	3215	2611	2656	2583	3544	3508	3628	3792	4550
Machinery	6465	7347	7057	7103	7362	7892	7801	7986	8295	8668
Non-ferrous metals	813	1381	1955	2089	1903	2263	2235	2223	2283	2407
Non-metallic minerals	1651	1914	1624	1567	1647	1930	2047	2170	2300	2306
Non-specified industry	2402	3864	5938	6291	6537	6980	7105	7036	6984	6922
Paper pulp and printing	3226	4009	3780	4160	4058	4152	4090	3880	3793	3824
Textile and leather	3047	3327	2531	2492	2320	2596	2635	2581	2304	2242
Transport equipment	2891	3852	3747	4314	5177	5070	5008	5119	5260	5157

Appendix 4. Available data for energy consumption per sector and per country (ktoe from IEA Energy Balance)

Albania	2000	2001	2002	2003	2004	2005	2006
Chemical and petrochemical	14	16	24	24	16	18	37
Food and tobacco	68	72	50	48	33	41	37
Iron and steel	32	35	26	31	38	34	29
Non-metallic minerals	10	11	7	11	7	9	9
Non-specified industry	4	5	16	6	3	18	3
Paper pulp and printing	13	12	30	23	10	12	12
Textile and leather	41	42	31	28	35	15	20

Argentina	1995	1996	1997	1998	1999	2000	2001	2002
Food and tobacco	667	701	716	769	830	816	788	750
Iron and steel	1488	1584	1511	1629	1403	1580	1434	1513
Non-ferrous metals	104	206	191	318	527	554	339	426
Non-metallic minerals	997	960	1094	1154	1004	867	775	665
Non-specified industry	7857	8400	10288	10760	10504	10391	11126	10548
Paper pulp and printing	310	330	329	323	271	300	262	267
Textile and leather	79	86	78	99	85	100	102	87
Transport equipment	67	66	111	83	65	63	46	34
Wood	30	31	36	35	32	37	30	33

Azerbaijan	2001	2002	2003	2004	2005	2006
Chemical and petrochemical	696	600	746	564	604	950
Food and tobacco	5	12	15	22	25	39
Iron and steel	2	11	124	18	20	34
Machinery	1	3	4	3	3	3
Non-ferrous metals	16	14	49	65	78	237
Paper pulp and printing	10	0	0	0	0	1
Textile and leather	0	1	2	2	2	5

Brazil	1996	1997	1998	1999	2000	2001	6600	2003	2004	2005
Chemical and petrochemical	5102	5801	5497	6100	6215	6241	15810	6715	6721	6856
Food and tobacco	11625	12246	13544	14369	12796	14507	12294	16595	17528	17846
Iron and steel	10976	11092	10589	11096	11944	11553	4462	13242	15005	14870
Non-ferrous metals	4007	3803	3907	4023	4322	4034	6079	5001	5243	5372
Non-metallic minerals	5451	5936	6195	6216	6388	6222	5340	5824	5793	6165
Non-specified industry	4267	4745	4940	4929	5430	5142	6570	5333	5780	5961
Paper pulp and printing	5081	5105	5539	5977	6229	6149	1108	7266	7267	7656
Textile and leather	1114	1033	1034	1022	1119	1046	6600	1067	1171	1187

Bulgaria	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Chemical and petrochemical	2172	1907	1549	1062	1073	1092	928	1003	978	990	1002
Food and tobacco	412	361	333	325	314	295	294	269	288	296	290
Iron and steel	953	1015	864	564	594	645	605	731	653	607	658
Machinery	278	233	210	146	133	124	119	121	113	123	122
Non-ferrous metals	215	191	191	173	164	161	126	138	158	155	157
Non-metallic minerals	918	808	612	507	510	508	548	559	596	618	679
Non-specified industry	33	163	135	83	65	62	61	76	105	86	88
Paper pulp and printing	152	153	135	99	103	75	141	162	193	195	165
Textile and leather	169	167	165	132	115	115	115	127	124	120	125
Transport equipment	29	22	19	16	12	13	18	11	11	11	10
Wood and wood products	66	59	52	48	47	50	55	58	60	57	74

Chile	2001	2002	2003	2004	2005	2006
Chemical and petrochemical	65	65	85	72	68	64
Iron and steel	396	400	402	348	459	467
Non-metallic minerals	229	207	275	310	270	352
Non-specified industry	2698	2409	2625	2619	2444	2721
Paper pulp and printing	1040	1220	935	1188	1318	1586

Colombia	2000	2001	2002	2003	2004	2005
Chemical and petrochemical	1124	1289	1242	1362	1329	1395
Food and tobacco	2102	1986	1838	2048	2007	1997
Iron and steel	701	669	621	618	618	634
Machinery	305	325	385	174	155	145
Non metallic minerals	1526	1586	1072	1524	1461	1571
Non-specified industry	193	159	235	217	218	210
Paper pulp and printing	727	727	1267	648	626	651
Textile and leather	504	459	470	430	435	433
Wood and wood products	69	43	91	50	46	53

Estonia	2000	2001	2002	2003	2004	2005	2006
Chemical and petrochemical	46	41	39	68	47	53	53
Food and tobacco	86	91	89	69	80	84	76
Machinery	20	22	25	35	31	36	40
Non-metallic minerals	104	144	83	105	94	129	129
Non-specified industry	51	57	56	60	61	57	50
Paper pulp and printing	43	41	44	43	34	31	46
Textile and leather	51	53	51	64	53	46	45
Transport equipment	7	5	6	8	11	10	11
Wood and wood products	77	90	106	136	149	162	118

Georgia	2001	2002	2003	2004	2005	2006
Chemical and petrochemical	7	35	39	45	32	35
Food and tobacco	24	19	20	24	26	14
Iron and steel	40	45	57	36	37	37
Machinery	1	1	1	1	1	1
Non-metallic minerals	63	54	62	73	84	26
Non-specified industry	47	47	51	48	47	118
Paper pulp and printing	0	0	0	0	0	0
Textile and leather	1	1	1	1	1	0
Transport equipment	5	4	5	5	6	2

India	1998	1999	2000	2001	2002	2003	2004
Chemical and petrochemical	7154	6655	6532	6377	5972	5286	5502
Food and tobacco	7371	8202	8087	7856	7988	7773	8055
Iron and steel	9664	9353	10601	10480	13384	13403	14779
Machinery	655	826	750	690	772	640	591
Non-ferrous metals	452	438	505	475	353	394	658
Non-metallic minerals	9449	9972	9842	9541	9770	9668	9928
Non-specified industry	49275	50778	46688	47269	48279	48830	51316
Paper pulp and printing	1730	1355	1266	1331	1290	1310	1352
Textile and leather	2287	2173	2013	1929	1608	1189	1405

Indonesia	1999	2000	2001	2002	2003	2004	2005
Chemical and petrochemical	1036	1042	1084	1078	918	761	954
Food and tobacco	771	763	800	812	718	706	876
Iron and steel	1919	1669	1655	1570	1297	919	1052
Machinery	68	66	70	73	67	77	94
Non-ferrous metals	569	699	136	146	124	141	133
Non-specified industry	17800	20227	19770	20622	18171	20222	22581
Paper pulp and printing	511	481	507	308	1050	715	732
Textile and leather	1268	1245	1313	1342	1205	1257	1555

Latvia	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Chemical and petrochemical	82	117	62	94	48	30	15	18	18	17	17	17	19
Food and tobacco	161	172	178	188	190	154	142	142	145	128	139	143	139
Machinery	36	30	29	30	29	25	21	27	23	25	25	29	30
Non-metallic minerals	104	103	99	80	82	81	65	69	88	104	98	118	117
Non-specified industry	20	29	27	23	15	13	12	12	14	18	23	26	27
Paper pulp and printing	12	10	9	7	6	7	7	8	9	10	10	11	12
Textile and leather	71	57	53	53	57	57	54	53	53	52	49	34	27
Transport equipment	17	19	26	15	13	12	10	10	11	13	11	12	14
Wood and wood products	58	53	73	76	97	93	83	102	90	92	117	136	164

Lithuania	2001	2002	2003	2004	2005	2006
Chemical and petrochemical	146	169	187	202	221	266
Food and tobacco	154	168	172	165	173	178
Iron and steel	5	4	3	4	5	5
Machinery	60	66	67	76	72	46
Non-metallic minerals	155	159	160	168	193	234
Non-specified industry	26	32	40	47	52	52
Paper pulp and printing	49	34	31	22	24	24
Textile and leather	71	76	79	73	67	67
Transport equipment	13	16	13	12	10	10
Wood and wood products	47	91	105	112	117	111

Macedonia	1997	1998	1999	2000	2001
Chemical and petrochemical	61	10	18	8	11
Food and tobacco	43	54	46	81	43
Iron and steel	195	284	188	167	159
Machinery	10	15	11	8	8
Non-metallic minerals	33	64	73	110	117
Non-specified industry	29	16	3	14	7
Paper pulp and printing	4	6	6	6	4
Textile and leather	45	42	33	29	22
Transport equipment	2	4	6	4	4
Wood and wood products	9	3	7	5	2

Morocco	2000	2001	2002	2003	2004	2005	2006
Chemical and petrochemical	34	66	67	78	77	74	85
Food and tobacco	37	50	53	57	59	83	85
Machinery	19	29	34	38	41	55	102
Non-metallic minerals	72	156	164	174	763	789	865
Non-specified industry	1470	1354	1284	988	698	900	748
Paper pulp and printing	28	10	12	12	12	12	12
Textile and leather	44	31	33	34	31	32	33

Philippines	1996	1997	1998	1999	2001	2003	2005
Chemical and petrochemical	392	411	414	483	348	364	354
Food and tobacco	1784	1818	1950	1795	1867	2018	2084
Iron and steel	413	424	425	414	363	344	298
Machinery	141	175	221	314	343	401	442
Non-metallic minerals	1372	1499	1513	1256	1172	1368	1535
Non-specified industry	57	61	67	62	62	44	60
Paper pulp and printing	230	185	241	254	221	234	237
Textile and leather	256	257	296	259	238	206	212
Wood and wood products	32	25	20	22	18	23	19

Republic of Moldova	2001	2002	2003	2004	2005	2006
Food and tobacco	175	153	166	249	263	243
Iron and steel	0	0	0	0	0	0
Machinery	6	5	6	6	7	7
Non-metallic minerals	30	18	21	26	27	27
Non-specified industry	56	65	69	52	56	48
Paper pulp and printing	5	7	8	23	25	24
Textile and leather	10	9	10	13	14	14
Wood and wood products	2	2	2	3	3	3

Romania	1990	1992	1994	1996	1998	2000	2001	2002	2003	2004	2005	2006
Chemical and petrochemical	8949	3560	4729	4206	1810	2147	2622	2890	3116	2416	2506	2238
Food and tobacco	190	1122	1475	1388	820	643	786	745	704	887	982	566
Iron and steel	5224	2930	3484	3286	3025	2181	2005	1892	2016	2398	2513	2556
Machinery	576	1950	1330	1639	1106	700	788	811	637	596	518	505
Non-metallic minerals	102	1378	1120	1207	1032	979	1004	1030	614	789	812	903
Non-specified industry	8346	401	299	430	505	371	225	344	440	455	335	207
Paper pulp and printing	121	389	376	371	273	319	295	356	477	286	266	251
Textile and leather	135	658	404	427	492	287	320	420	350	338	191	266
Wood and wood products	80	314	209	199	161	171	187	200	121	229	202	243

Russian Federation	2001	2002	2003	2004	2005	2006
Chemical and petrochemical	27945	27525	27402	26448	26448	26582
Food and tobacco	8426	8640	8149	7860	7860	8145
Iron and steel	31982	32464	32843	32870	32870	36533
Machinery	16246	15084	14250	13972	13972	5528
Non-ferrous metals	18656	18748	18686	18762	18762	8512
Non-metallic minerals	9400	9516	9995	10578	10578	14557
Non-specified industry	3352	3711	3461	3262	3262	5971
Paper pulp and printing	500	441	423	541	541	6572
Textile and leather	1713	1614	1495	1349	1349	1259
Wood and wood products	8089	8230	8210	8307	8307	1981

South Africa	1993	1996	1999	2000	2001	2002	2003	2004	2005	2006
Chemical and petrochemical	1199	1371	1244	1268	959	983	977	1046	1822	2137
Food and tobacco	48	102	105	109	78	80	85	82	88	95
Iron and steel	3513	3934	4369	4517	4501	4637	4450	4824	4868	4843
Machinery	99	128	33	34	46	46	51	45	49	54
Non-ferrous metals	558	1143	1323	1342	1305	1328	1398	1544	1603	1603
Non-metallic minerals	1140	1103	1133	1103	793	942	1319	1525	1618	877
Non-specified industry	6129	7471	8481	8425	7333	8607	8616	8533	7714	7892
Paper pulp and printing	83	92	152	192	191	189	180	178	201	218
Textile and leather	34	54	44	41	42	45	45	45	45	45
Transport equipment	4	5	9	14	7	8	8	7	8	8
Wood and wood products	47	61	56	41	22	25	23	25	26	26

Appendix 5. Energy intensity per country and per sector (ktoe/ 2006 PPP $) in 001

	Chem.	Food	Iron	Mach.	Non ferrous metals	Non metallic minerals	Other	Paper	Textile	Transport	Wood
Albania	1.78	1.36	1.04			0.25	0.33	0.57	0.47		
Argentina		0.08	0.98		1.15	0.52	5.60	0.08	0.04	0.03	0.10
Azerbaijan	11.75	0.01	0.21	0.02	1.94			0.95	0.01		
Brazil	0.20	0.29	0.99		0.85	0.58	0.30	0.29	0.06		
Bulgaria	1.72	0.28	4.45	0.11	1.50	1.48	0.20	0.29	0.12	0.26	0.66
Chile	0.01		1.38			0.14	1.70	0.28			
Colombia	0.25	0.20	0.70	0.17		0.62	0.06	0.26	0.13		0.29
Estonia	0.42	0.27		0.08		1.06	0.19	0.24	0.17	0.10	0.36
Georgia	0.42	0.16	1.79	0.05		2.64	5.84	0.03	0.17	0.15	
India	0.23	0.43	1.06	0.03	0.14	1.20	5.07	0.27	0.13		
Indonesia	0.11	0.04	0.47	0.01	0.12		3.01	0.09	0.12		
Latvia	0.21	0.26	0.12	0.78		0.07	0.04	0.20		0.10	0.22
Lithuania	8.25	0.84	1.60	0.67		5.99	0.41	1.04	0.58	0.09	1.08
Macedonia	0.08	0.07	0.82	0.06		0.61	0.08	0.03	0.07	0.09	0.10
Morocco	0.05	0.01	0.03			0.14	3.00	0.02	0.02		
Philippines	0.13	0.34	0.55	0.04		1.37	0.04	0.24	0.11		0.12
R. Mold.		0.28	0.09	0.09		0.31	1.47	0.14	0.12		0.27
Romania	1.59	0.07	1.74	0.16		0.59	0.08	0.23	0.08		0.14
Russia	1.87	0.25	2.32	0.48	0.97	0.81	0.36	0.06	0.43		2.40
S. Africa	0.28	0.01	1.74	0.01	0.69	0.48	1.12	0.05	0.02	0.00	0.02

Appendix 6. The Fisher Ideal Index decomposition in different countries

Albania	Fisher Ideal Index	Structural effect	Energy efficiency effect
2000	1.00	1.00	1.00
2001	0.93	0.98	0.95
2002	0.73	1.00	0.73
2003	0.65	0.96	0.67
2004	0.49	1.06	0.46
2005	0.43	1.09	0.39
2006	0.35	1.09	0.32

Argentina	Fisher Ideal Index	Structural effect	Energy efficiency effect
1995	1.00	1.00	1.00
1996	1.04	1.02	1.02
1997	1.09	1.15	0.95
1998	1.23	1.25	0.98
1999	1.34	1.17	1.14
2000	1.42	1.21	1.17
2001	1.46	1.12	1.30
2002	1.16	1.12	1.04

Azerbaijan	Fisher Ideal Index	Structural effect	Energy efficiency effect
2001	1.00	1.00	1.00
2002	0.70	1.12	0.63
2003	0.72	0.85	0.85
2004	0.47	0.96	0.49
2005	0.53	1.51	0.35
2006	0.96	1.47	0.65

Brazil	Fisher Ideal Index	Structural effect	Energy efficiency effect
1996	1.00	1.00	1.00
1997	1.04	1.03	1.01
1998	1.12	1.03	1.09
1999	1.07	1.04	1.03
2000	1.02	1.08	0.95
2001	0.99	1.07	0.92
2002	1.00	1.11	0.90
2003	0.98	1.12	0.88
2004	0.97	1.17	0.83
2005	1.04	1.15	0.91

Bulgaria	Fisher Ideal Index	Structural effect	Energy efficiency effect
1996	1.00	1.00	1.00
1997	1.13	0.98	1.16
1998	1.31	0.79	1.66
1999	1.10	0.63	1.74
2000	1.05	0.95	1.10
2001	1.14	0.82	1.40
2002	1.07	0.73	1.47
2003	0.98	0.81	1.21
2004	0.86	0.89	0.96
2005	0.75	0.84	0.90

Chile	Fisher Ideal Index	Structural effect	Energy efficiency effect
2001	1.00	1.00	1.00
2002	0.96	1.01	0.95
2003	0.84	0.85	0.99
2004	0.87	0.84	1.03
2005	0.73	0.68	1.07
2006	1.00	0.80	1.25

Colombia	Fisher Ideal Index	Structural effect	Energy efficiency effect
2000	1.00	1.00	1.00
2001	0.97	0.99	0.98
2002	0.92	1.00	0.92
2003	0.88	1.04	0.85
2004	0.83	1.04	0.79
2005	0.84	1.01	0.84

Estonia	Fisher Ideal Index	Structural effect	Energy efficiency effect
2000	1.00	1.00	1.00
2001	1.07	1.02	1.05
2002	0.90	1.03	0.87
2003	0.94	1.01	0.93
2004	0.84	1.03	0.82
2005	0.89	1.03	0.87
2006	0.92	1.12	0.82

Georgia	Fisher Ideal Index	Structural effect	Energy efficiency effect
2001	1.00	1.00	1.00
2002	1.27	0.58	2.18
2003	1.22	0.79	1.54
2004	0.95	0.56	1.69
2005	0.88	0.75	1.17
2006	0.68	1.28	0.53

India	Fisher Ideal Index	Structural effect	Energy efficiency effect
1998	1.00	1.00	1.00
1999	0.94	1.13	0.83
2000	0.99	1.04	0.96
2001	1.04	1.16	0.89
2002	1.00	1.11	0.90
2003	0.92	1.14	0.81
2004	0.82	1.14	0.72

Indonesia	Fisher Ideal Index	Structural effect	Energy efficiency effect
1999	1.00	1.00	1.00
2000	0.98	0.93	1.05
2001	0.95	0.99	0.96
2002	1.04	0.91	1.15
2003	0.85	0.87	0.98
2004	0.90	1.10	0.82
2005	0.95	0.99	0.96

Latvia	Fisher Ideal Index	Structural effect	Energy efficiency effect
1994	1.00	1.00	1.00
1995	1.35	0.99	1.35
1996	1.46	0.98	1.49
1997	1.57	1.04	1.51
1998	1.66	1.02	1.63
1999	2.24	1.04	2.16
2000	2.14	0.99	2.18
2001	2.33	1.05	2.22
2002	2.15	1.01	2.12
2003	2.07	1.02	2.03
2004	2.17	1.06	2.04
2005	2.08	1.08	1.92
2006	2.00	1.15	1.75

Lithuania	Fisher Ideal Index	Structural effect	Energy efficiency effect
2001	1.00	1.00	1.00
2002	1.04	1.14	0.92
2003	0.95	1.11	0.85
2004	0.72	1.14	0.63
2005	0.63	1.21	0.52
2006	0.60	1.36	0.45

Macedonia	Fisher Ideal Index	Structural effect	Energy efficiency effect
1997	1.00	1.00	1.00
1998	1.18	0.96	1.23
1999	0.91	0.97	0.94
2000	0.99	1.07	0.93
2001	0.93	1.02	0.91

Morocco	Fisher Ideal Index	Structural effect	Energy efficiency effect
2000	1.00	1.00	1.00
2001	0.98	1.01	0.97
2002	0.90	0.93	0.97
2003	0.77	0.93	0.83
2004	0.96	0.94	1.03
2005	0.99	0.89	1.12
2006	1.02	0.94	1.08

Philippines	Fisher Ideal Index	Structural effect	Energy efficiency effect
1996	1.00	1.00	1.00
1997	0.94	0.97	0.97
1998	0.81	0.91	0.89
1999	0.74	0.88	0.85
2001	0.87	0.78	1.12
2003	1.13	0.85	1.34
2005	1.05	0.81	1.30

Republic of Moldova	Fisher Ideal Index	Structural effect	Energy efficiency effect
2001	1.00	1.00	1.00
2002	0.90	0.98	0.91
2003	0.88	1.01	0.87
2004	1.15	1.01	1.14
2005	1.24	1.01	1.23
2006	1.16	1.00	1.16

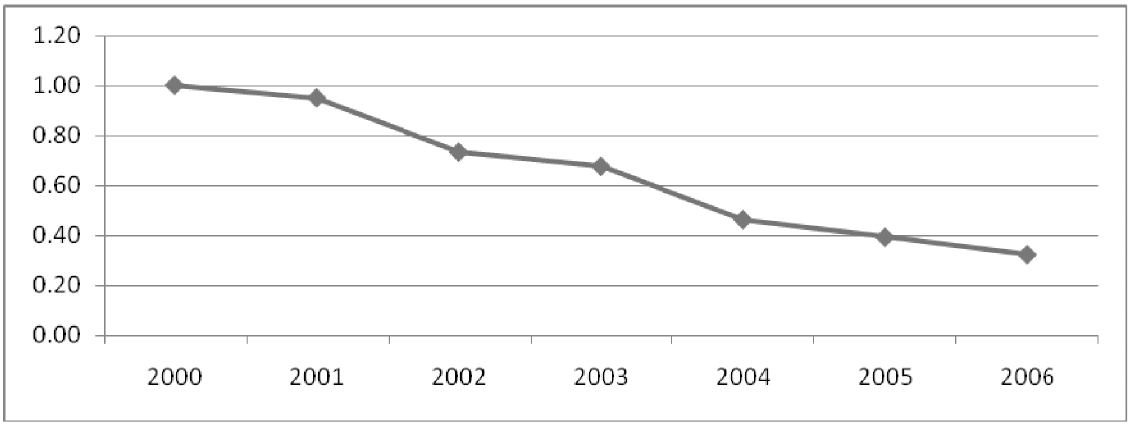
Romania	Fisher Ideal Index	Structural effect	Energy efficiency effect
1990	1.00	1.00	1.00
1991	1.03	1.18	0.87
1992	0.77	1.33	0.58
1993	0.79	1.23	0.64
1994	0.80	1.32	0.60
1995	0.79	1.30	0.61
1996	0.69	1.16	0.59
1997	0.70	1.06	0.66
1998	0.75	1.14	0.66
1999	0.70	1.01	0.69
2000	0.61	1.06	0.57
2001	0.57	1.01	0.57
2002	0.60	1.00	0.60
2003	0.94	1.29	0.73
2004	0.88	1.41	0.62
2005	0.96	1.34	0.71
2006	0.87	1.38	0.63

Russian Federation	Fisher Ideal Index	Structural effect	Energy efficiency effect
2001	1.00	1.00	1.00
2002	0.70	1.09	0.64
2003	0.86	1.08	0.79
2004	0.74	1.12	0.66
2005	0.74	1.12	0.66
2006	0.64	1.12	0.57

South Africa	Fisher Ideal Index	Structural effect	Energy efficiency effect
1993	1.00	1.00	1.00
1996	0.99	1.20	0.83
1999	1.08	1.35	0.80
2000	1.03	1.34	0.77
2001	0.90	1.32	0.68
2002	0.91	1.43	0.64
2003	0.92	1.42	0.65
2004	0.94	1.40	0.67
2005	0.94	1.37	0.68
2006	0.89	1.39	0.64

Appendix 7. The energy efficiency effect per country

Albania



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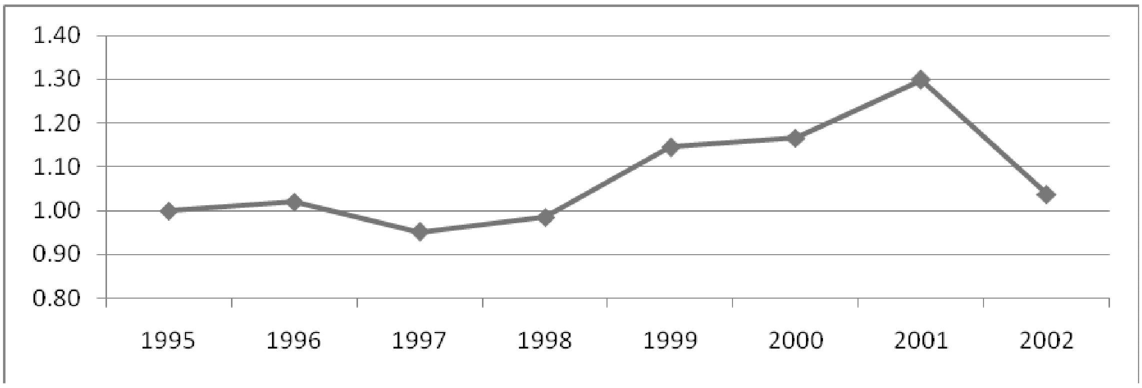

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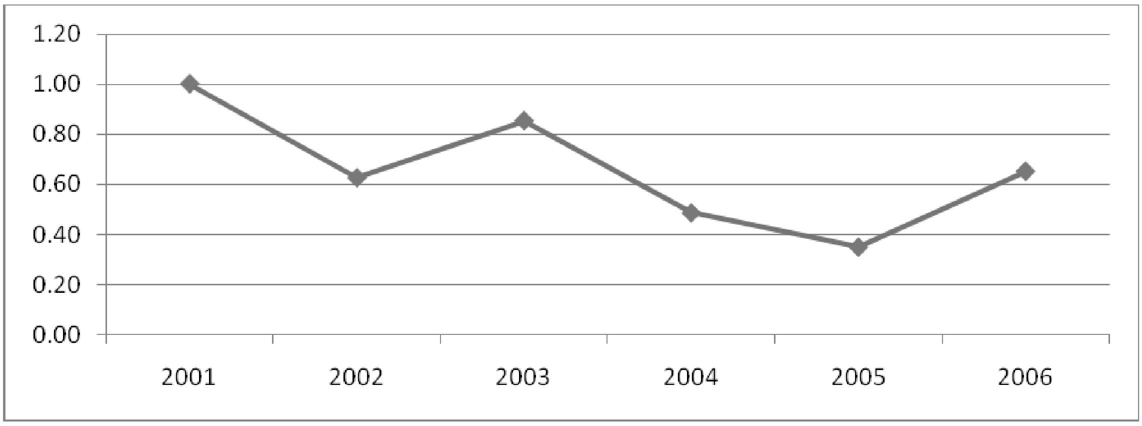

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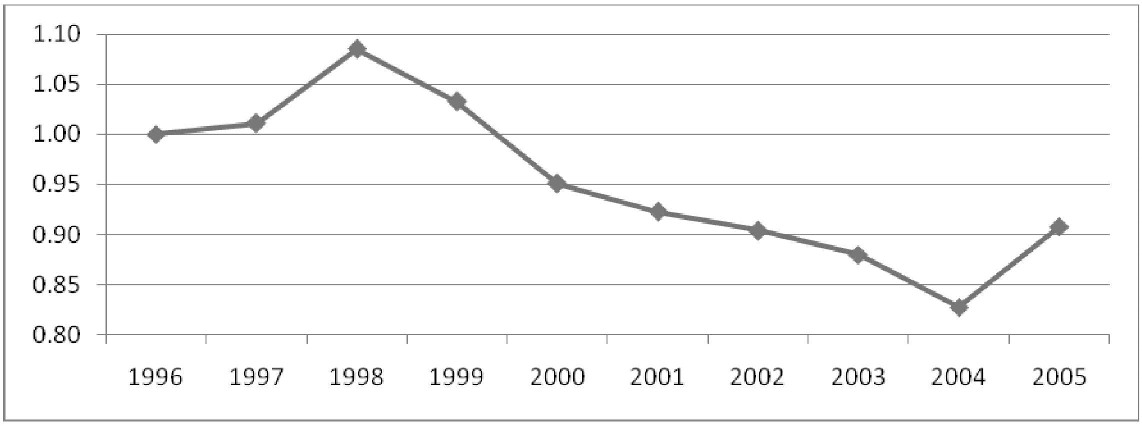

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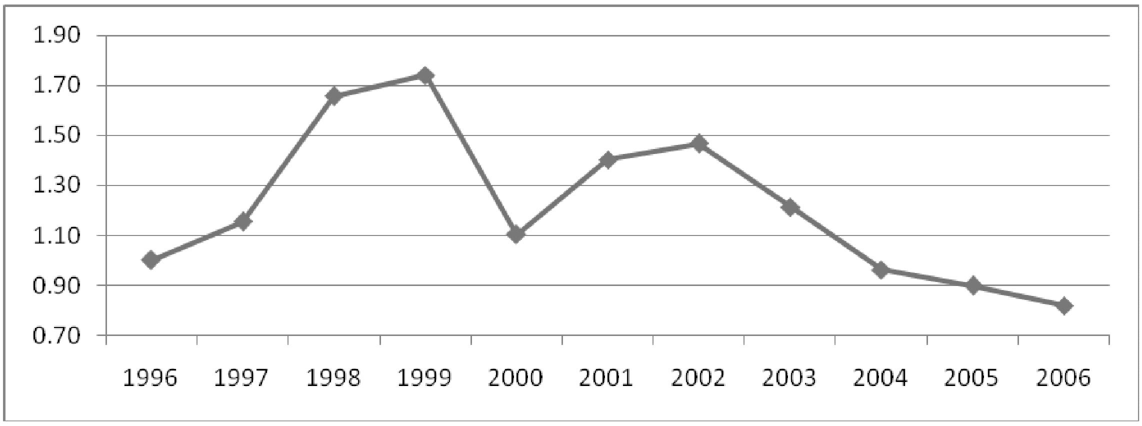

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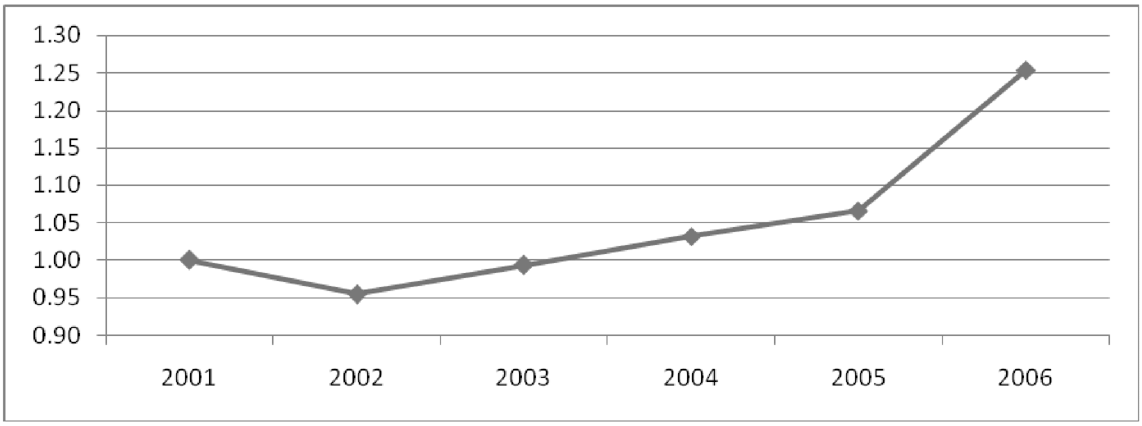

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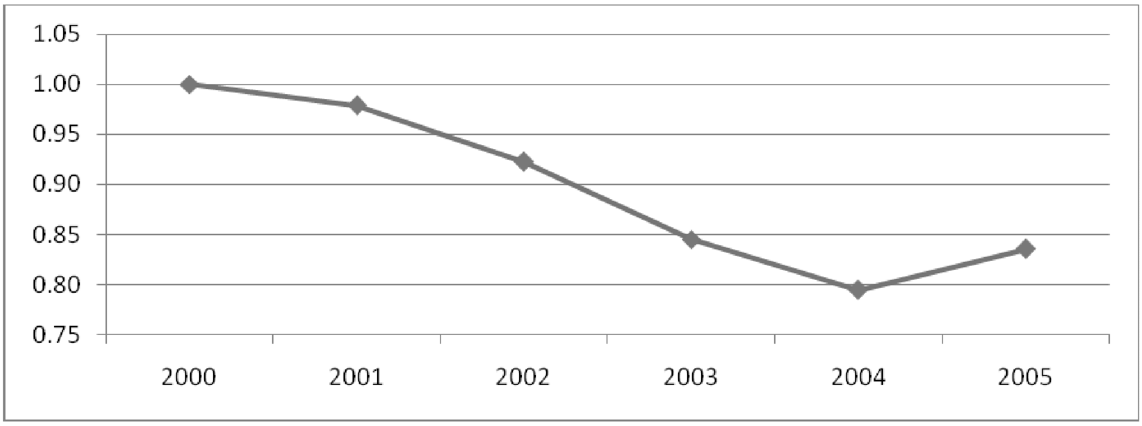

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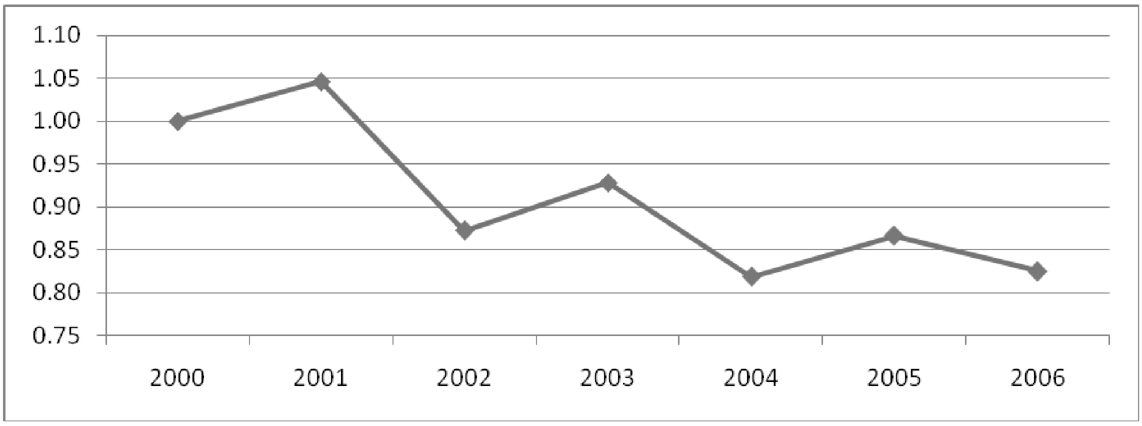

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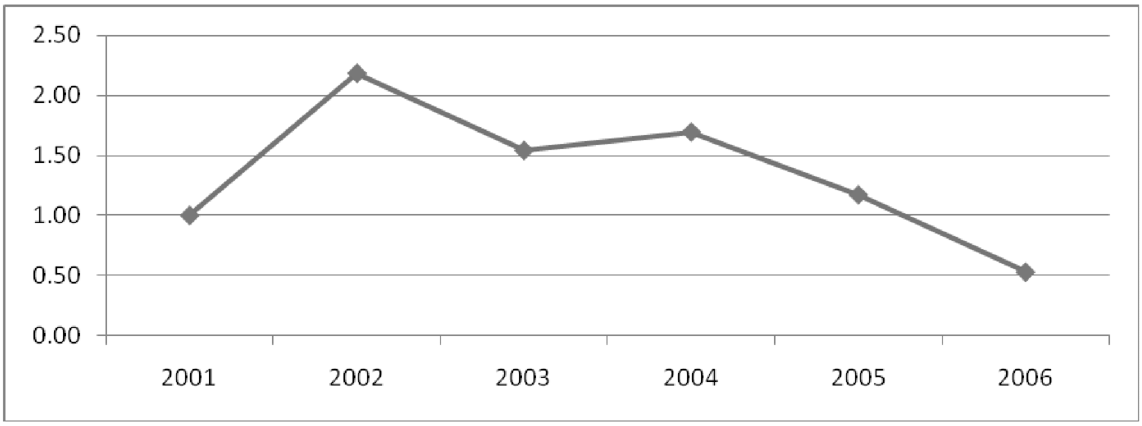

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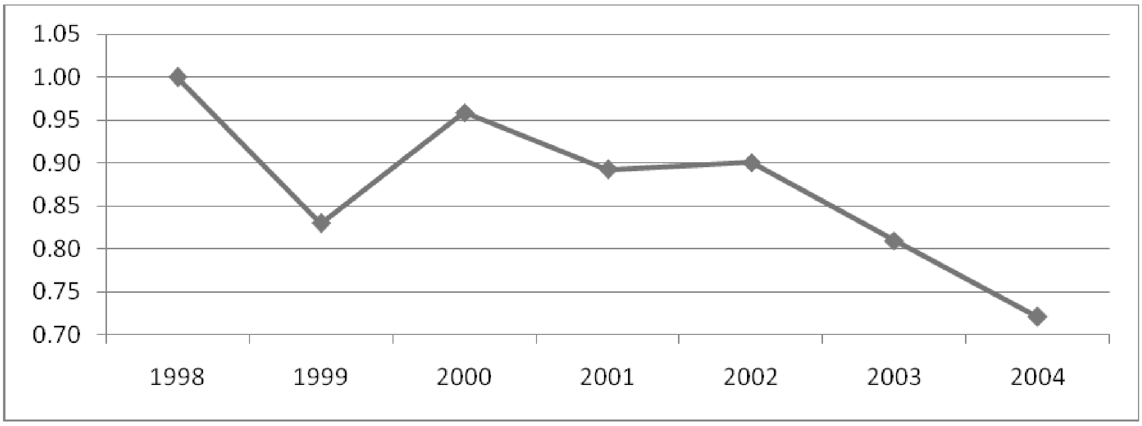

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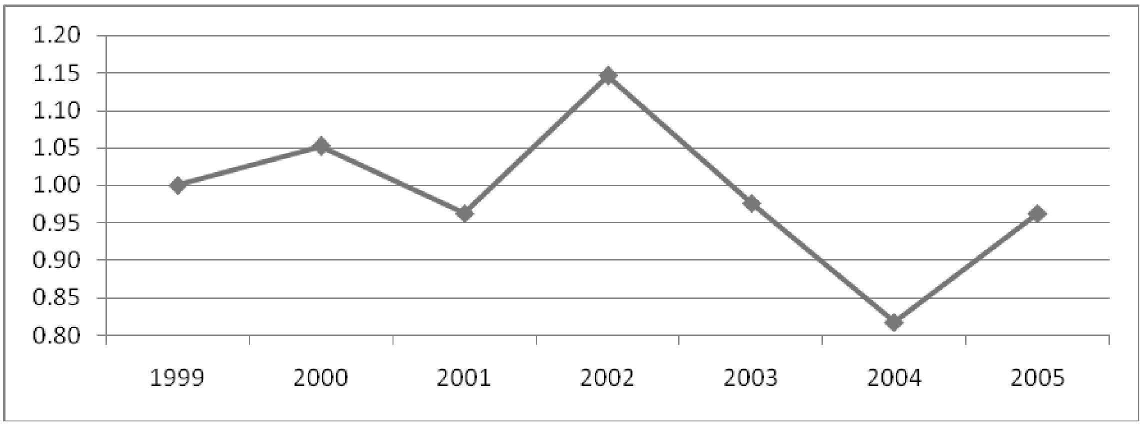

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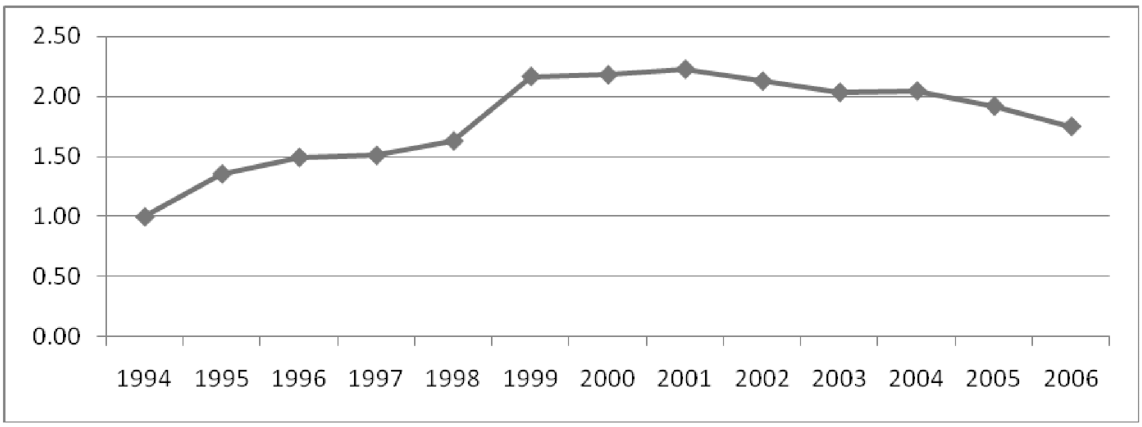

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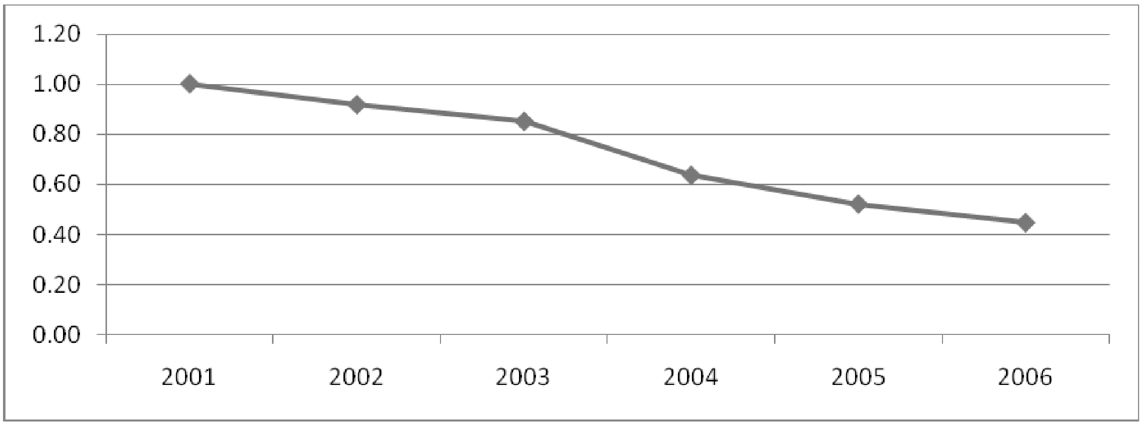

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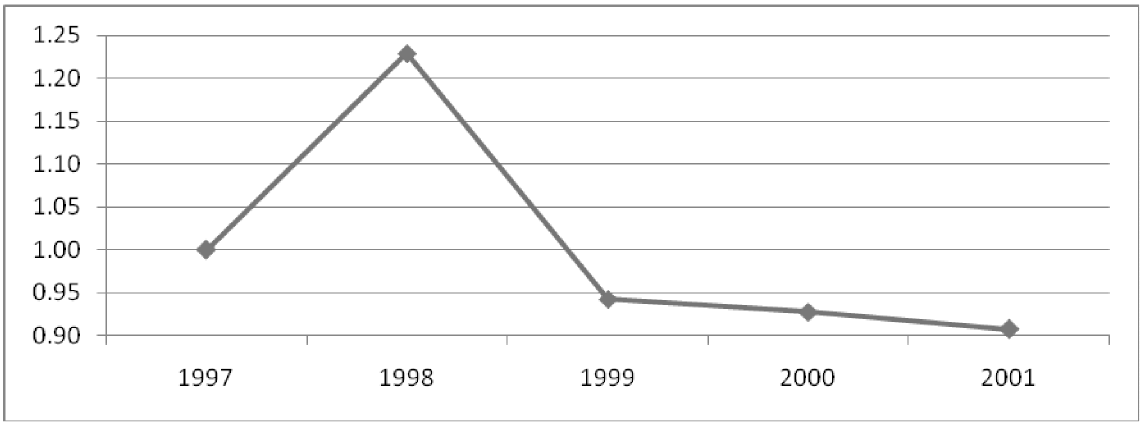

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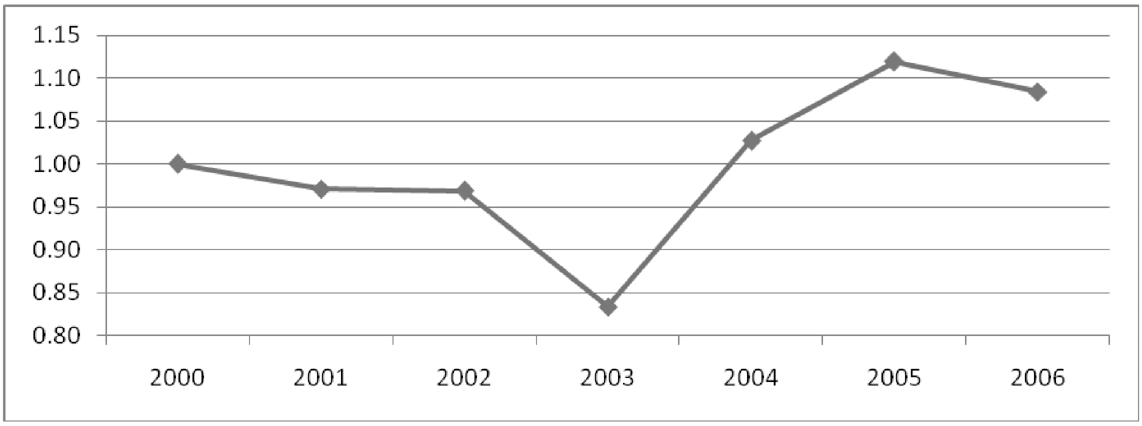

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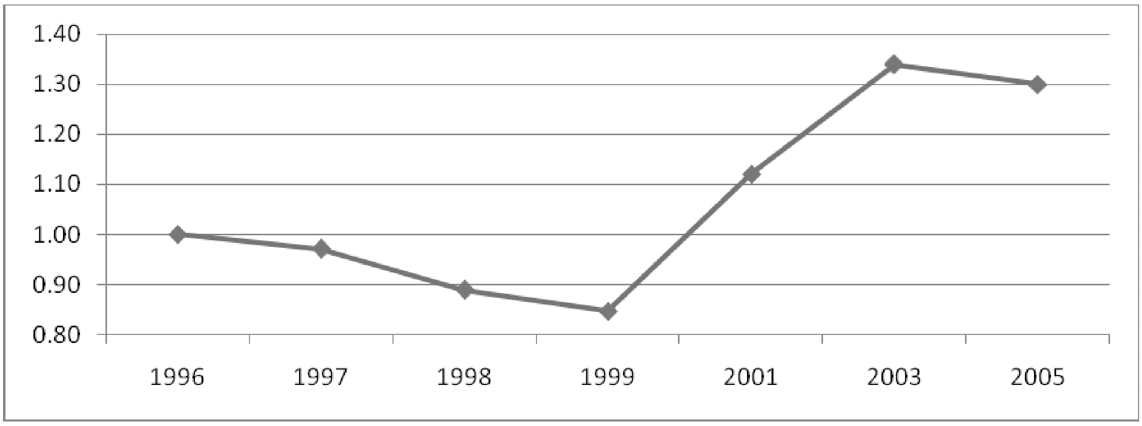
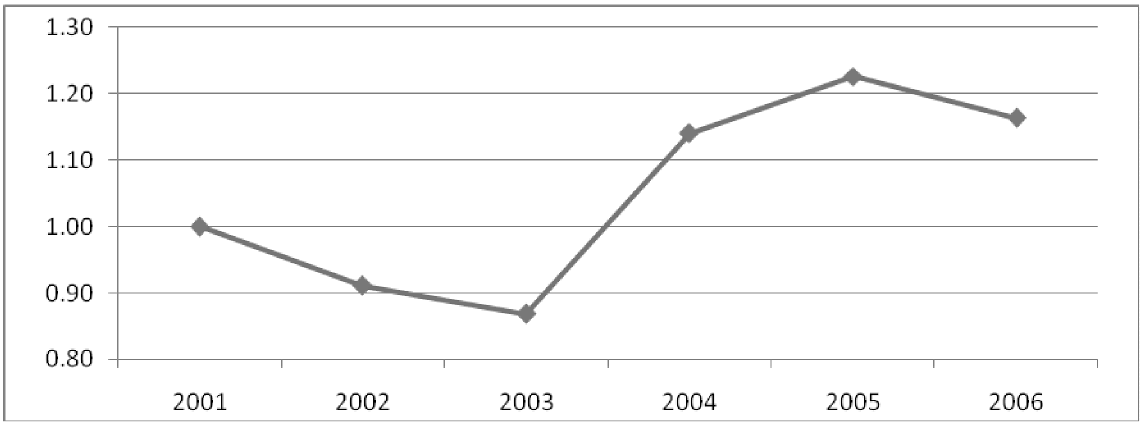


Republic of Moldova



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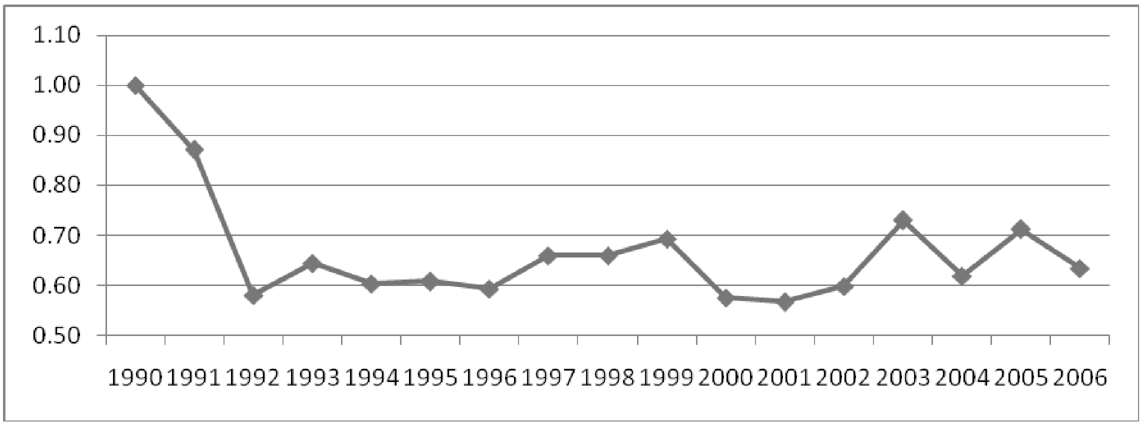

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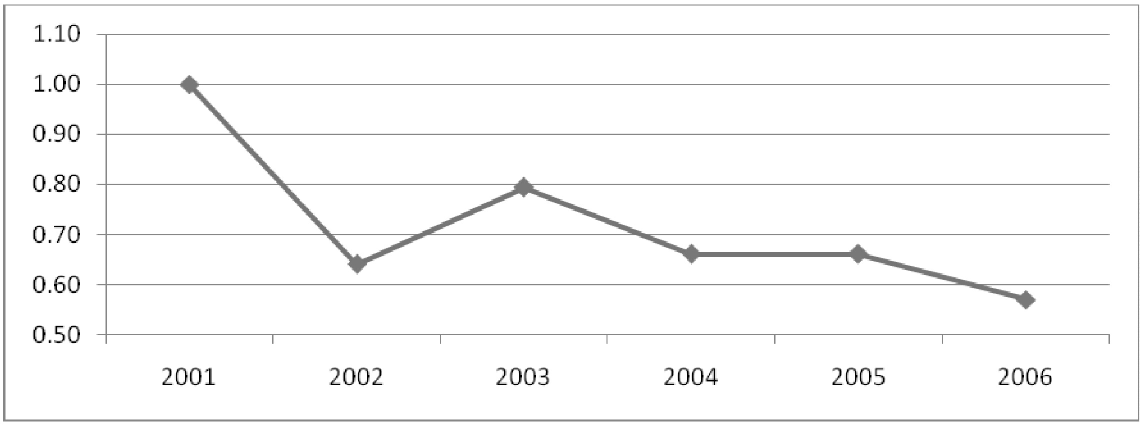

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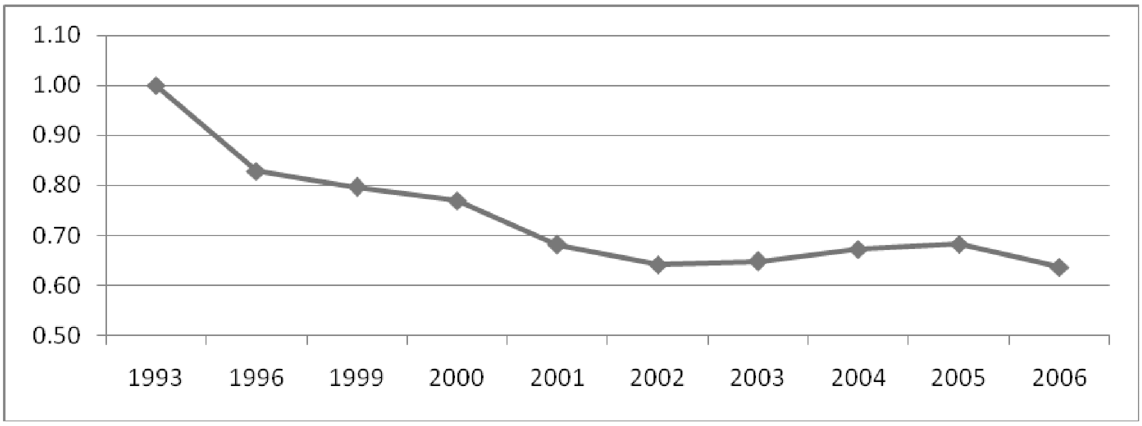

V. Factors affecting energy efficiency adoption in the manufacturing sector in developing countries

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1. Introduction

Energy efficiency represents an achievement that would allow firms in developing countries to boost growth through a reduction of the energy consumption bill and to reduce emissions that are contributing to global warming. In spite of the literature providing evidence that energy efficiency pays from an economic point of view in developing countries (Farrel and Rimes 2009), quantitative studies that try to understand the determinants of energy efficiency technology adoption at firm level are still lacking (background paper ODI 2010).

In this paper we will fill this gap by exploiting UNIDO questionnaires to firms in Viet Nam, Philippine, Singapore and Moldova. As we have outlined in the background paper (ODI 2010) there is a wide set of factors affecting choices of firms to invest in energy efficiency. For this reason we need a reference document to set the criteria that can drive the modeller to run a quantitative analysis and to identify the main energy efficiency adoption factors that are relevant from a policy point of view.

UNIDO in a background paper (2007) specifies a menu of useful actions that could be adopted in developing countries to boost energy efficiency:

Target setting agreements. Target-setting agreements, also known as voluntary or negotiated agreements, have been used by a number of governments as a mechanism for promoting energy efficiency within the industrial sector. A recent survey of such target-setting agreement programs identified 23 energy efficiency or GHG emissions reduction voluntary agreement programs in 18 countries, including countries in Europe, the U.S., Canada, Australia, New Zealand, Japan, South Korea, and Chinese Taipei (Taiwan).

Energy management standards. The purpose of an energy management standard is to provide guidance for industrial facilities to integrate energy efficiency into their management practices, including fine-tuning production processes and improving the energy efficiency of industrial systems.

Capacity building. A carefully organized training program can have a significant impact. As a result of the United Nations Industrial Development (UNIDO) China Motor System Energy Conservation Program, 22 engineers were trained in system optimization techniques in Jiangsu and Shanghai provinces. The trainees were a mix of plant and consulting engineers. Within two years after completing training, these experts conducted 38 industrial plant assessments and identified nearly 40 million kWh in energy savings.

Documenting for sustainability. With the renewed interest in energy efficiency worldwide and the emergence of carbon trading and new financial instruments such as white certificates, there is a need to introduce greater transparency into the way that industrial facilities identify, develop, and document energy efficiency projects. In order to ensure persistence for energy efficiency savings from system optimization projects, a method of verifying the on-going energy savings under a variety of operating conditions is required. ISO 9000/14000 Series Standards would require continuously monitoring an organization's adherence to the new energy system-operating paradigm.

Tax and fiscal policies. Tax and fiscal policies for encouraging investment in energy-efficient industrial equipment and processes operate either through increasing the costs associated with energy use to stimulate energy efficiency or by reducing the costs associated with energy efficiency investments.

From these words it is clear that UNIDO identifies the introduction of *specific targets*, *energy management*, *technical expertise*, *certification* and *external policies* as crucial factors driving the energy efficiency adoption. By exploiting the UNIDO questionnaire we will verify if variables related to these criteria will have a future impact on the firms` decisions to invest in energy efficiency.

2. Methodology and dataset

To run our analysis we will use discrete choice analysis techniques (Mc Fadden, 1976). The concept behind a simple logistic model is very simple, but the interpretation of the coefficients is slightly more complex than the simple linear regression.

1)

$$\log\left(\frac{\pi(adotpion)}{1-\pi(adoption)}\right) = \alpha + \beta x$$

The crucial feature of the simple logistic regression model is that the dependant variable is the probability of a categorical (0,1) rather than a continuous variable. For our modelling exercise we estimate factors that affect probability to adopt energy efficiency technology (adoption) vs the probability that the firm does not decide to invest in energy efficiency.

The coefficient β cannot be interpreted as in the linear regression. Coefficients should be interpreted as log odds ratio variations deriving from variations of the X independent variables. The SPSS software also provides results for $\exp^{b}$

2) $$\frac{\pi(adoption)}{1-\pi(adoption)} = e^{\alpha+\beta x} = e^{\alpha}\left(e^{\beta}\right)^{x}$$

representing odds ratio variations deriving from variations of the X independent variables. We use as dependant variable a question of the UNIDO firms` survey:

Is your company considering or planning to invest in energy efficiency projects over the next 5 years? (Y/N)

We are interested in verifying if the determinants of future energy efficiency investment decisions over time. To choose the explanatory variables we select questions according to the two following criteria:

1) We select those questions that are close to the actions priorities identified by the UNIDO background paper[7];
2) We select those sectors that guarantee the highest observations availability and countries coverage given the existing missing data.

Another methodology that we use in the paper is the principal component analysis that is applied to the energy efficiency adoption barriers used in our study. Principal component analysis (PCA) involves a mathematical procedure that transforms a number of possibly correlated variables into a smaller number of uncorrelated variables called principal components. The first principal component accounts for as much of the variability in the data as possible, and each succeeding component accounts for as much of the remaining variability as

[7] In Appendix 1 we explain the explanatory variables we use and the UNIDO policy priorities to which they belong according to our interpretation.

possible. This is a technique widely used in marketing analysis and is very useful to reduce the number of variables to introduce in the regression analysis. In our case the principal component analysis is used to reduce eight variables concerning the perception of respondents towards energy efficiency barriers (1 low significance – 4 high significance) in a smaller number of variables and to identify those barriers for which respondents show similar perceptions of relevance. Each component clusters a set of energy efficiency adoption barriers with a high level of correlation but is uncorrelated to other components.

We use for our analysis 241 observations of firms in Viet Nam, Philippines, Singapore and Moldova for 11 sectors[8]. The use of random samples is very spread in many relevant contributions of the discrete choice analysis literature (Train and Winston 2007).

3. Results

As first step we run our principal component analysis on the barriers to energy efficiency adoption variables. The questionnaire includes 17 barriers, but we choose those questions that are present in the questionnaire of all 4 countries. Interestingly the PCA creates two main components as showed in the table 1:

Table 15 Principal components analysis on the barriers to the adoption of energy efficiency. Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization

Variables	**Component 1**	**Component 2**
Top management commitment	.358	.446
Lack expertise energy efficiency projects	.607	.127
Production interruption	.059	.830
Lack of capital	.134	.668
Insufficient information on costs and benefits of energy efficiency	.702	.153
The market does not place any value added to energy efficiency	.755	-.019
Existing policies are inadequate to promote and support energy efficiency	.789	.279
Lack of external drivers such as mandatory CO2 emissions targets	.698	.305

[8] In Appendix 2 we include information about the dataset we have used for this analysis.

Table 16. % of variance captured by the two components

Rotation sums of squared loadings		
Total	% variance	% cumulative
2.691	33.635	33.635
1.546	19.321	52.956

Table 2 shows that the two components that have been created by the PCA analysis capture more than 50 percent of the initial information. The interpretation of the two components is very interesting. Whereas the component 1 is mainly determined by variables such as "The market does not place any value added to energy efficiency" and "Existing policies are inadequate to promote and support energy efficiency", Component 2 is mainly determined by barriers such as "Energy efficiency projects may interrupt production" and "Lack of capital". In other words whereas the Component 1 represents factors related to external conditions (market, policy), Component 2 represents microeconomic conditions (production process, inputs availability). Principal components that are extracted from our procedure can then be used as explanatory variables in our logistic regression analysis.

Results of our logit model provide very interesting insights.

Table 17. Results of the logit model. Dependant variable: is your company considering or planning to invest in energy efficiency projects in the next five years? (odds ratio YES/NOT). 116 observations.

Variable	**B**	**SE**	**Sign**	**df**	**Sig.**	**Exp(b)**
Constant	.159	1.459	.012	1	.913	1.172
Energy audit (YES)	2.705	1.119	5.842	1	.016	14.951
Staff awareness programs (YES)	-.311	1.358	.053	1	.819	.732
Existence energy policy (YES)	-.886	.988	.806	1	.369	.412
Existence energy performance indicators (YES)	-.447	.841	.282	1	.595	.640
Country: Philippines	1.141	.991	1.327	1	.249	3.131
Country: Moldova	-.331	1.647	.040	1	.841	.718
Planning or considering energy management innovation (YES)	1.909	.902	4.477	1	.034	6.747
Energy reduction targets (YES)	.762	1.060	.516	1	.472	2.142
Certification (YES)	-2.371	1.199	3.908	1	.048	.093
Investments in energy efficiency in the last two years (YES)	1.593	.949	2.816	1	.093	4.917
Component 1: external conditions	-.253	.436	.338	1	.561	.776
Component 2: microeconomic constraints	-1.133	.458	6.133	1	.013	.322
Number of employees	.001	.001	1.757	1	.185	1.001

A number of coefficients are found significant in our analysis with a 0.05 tolerance level. A positive (negative) impact on the dependant variable odds ratio is expressed by the condition $\exp b > 1 (\exp b < 1)$. On the basis of these results we can shape an identikit of the firms that are more likely to invest in energy efficiency in the next five years.

Firms that are more likely to plan or consider investing in energy efficient projects have already in place energy audits procedures and are already planning energy management innovations in the near term. In other terms firms that are ready to invest in energy efficiency are those having an internal organization that controls energy efficiency performances and that are the most dynamic from a management innovation point of view.

Targets related variables are not found to increase the likelihood to invest in energy efficiency. If we look at the “Existence of energy policy”, “Existence of energy performance indicators” and the “Existence of internal energy reduction targets” we do not find a significant coefficient.

The variable related to staff expertise “Does your company have staff awareness programs to encourage energy conservation” is also non-significant. It is surprising the finding related to the Certification variable: “Is your company using a management system standard?”. In this case we find a negative and significant coefficient. This result could be explained by the fact that firms` choice to adopt a certification system may offset further investments in energy efficiency. Firms` management may feel that the accomplishment of the standards is already an appropriate means to reach an efficient production process.

Finally, we find a sort of path dependency of firms in the innovation process. Firms that have already invested in energy efficiency (question “Did your company invest in energy efficient projects in the last two years”) are more likely to invest in the next five years. This finding is very interesting from a policy point of view. This means that the introduction of energy efficiency projects in developing countries` firms is crucial to guarantee they can continue to invest in energy efficiency in the future. This finding implies that international organizations such as UNIDO will be crucial to provide technical assistance with local projects to encourage the start up of energy efficiency innovations in developing countries. Local governments and international climate change agreements could be crucial to provide the necessary climate finance additional transfers to induce new innovation processes in developing countries.

In summary, we find that energy management and microeconomic factors rather than external conditions are the most important to introduce energy efficiency practices in developing countries` firms. This result is further confirmed by the finding that just Component 2 expressing microeconomic barriers to energy efficiency adoption shows a negative and significant sign. Component 1 that is mainly explained by external policy conditions is negative but not significant.

This result is quite interesting because it shows that just when firms perceive relevant microeconomic management conditions, they will more likely reduce investments in energy efficiency. This finding pushes the policy implication that "bottom up" oriented rather than broad macroeconomic policies could be more effective in encouraging the adoption of energy efficiency. Moreover interestingly the country location of firms is not a significant variable in our estimation.

The results that we have presented are quite robust. As showed by the table 4 the model correctly predicts 92 percent of dependant variables observations in a sample of 116 observations. We can just use 116 observations of the whole sample because of missing data. The percentage of correct No predictions is 67 percent, the percentage of correct YES predictions is 98 percent. Both values are higher than the frequency of the NO and YES observations in the restricted dataset with 116 observations (18 percent and 82 percent) and this represents further proof of the model robust fit. A good model performance is also showed by the Cox and Snell R square and the Nagelkerke R square.

Table 18. Logit model. Goodness of fit (I).

		Model forecast		**Percentage correct**
		NO	YES	
Observed data	NO	15	7	69.2
	YES	2	92	97.9
	Total correct	15+92 = 107		107/116 = 92.2

Table 19. Logit model. Goodness of fit (II)

Cox and Snell R square	**Nagelkerke R square**
0.411	0.657

As a final check we verify the most important business constraint reducing the likelihood to invest in energy efficiency among those contained in the table 1. Specifically we run the same regression as in Table 3 by replacing Component 1 and Component 2 deriving from our PCA analysis with specific business constraints. We run the same regression analysis as in the table 6 by including the whole set of 8 business constraints. We adopt a Likelihood Ratio forward selection procedure to identify the most meaningful variables and barriers affecting plans to adopt EE technology.

As is evident in Table 6, we confirm that microeconomic conditions affect the likelihood to invest in energy efficiency. With this revised model specification we confirm that propensity to energy management innovation and past experience in energy efficiency technology investments increase the likelihood that a firm in developing countries plans to introduce new technology. Interestingly, we also find that among the barriers, top management commitment is very relevant. In other words, we find that the more firms perceive top management's commitment as a business constraint the lower is the likelihood to invest in EE.

Table 20. Results of the logit model. Dependant variable: is your company considering or planning to invest in energy efficiency projects in the next five years? (odds ratio YES/NOT). 116 observations. LR test forward variable selection procedure

Variable	**B**	**SE**	**df**	**Sig.**	**Exp(b)**
Constant	1.434	1.165	1	.000	16.169
Investments in energy efficiency in the last two years (YES)	1.656	.711	1	.020	5.237
Planning or considering energy management innovation (YES)	1.978	.799	1	.013	7.227
Top management commitment is a poor relevant business constraint*	-3.532	1.158	1	.002	.029
Top management commitment is a relevant business constraint	-2.921	1.271	1	.022	.054
Top management commitment is a very relevant business constraint	-2.371	1.525	1	.120	.093

* We drop the dummy variable "Top management commitment is **a very poorly relevant** business constraint". The coefficients associated to the variables "Top management **– poorly relevant, relevant, very relevant**" represent the increase (+) or the decrease (-) of likelihood to invest in EE if compared to firms where the top management commitment is a very poor relevant business constraint.

Table 21. Revised logit model. Goodness of fit (I).

		Model forecast		**Percentage correct**
		NO	YES	
Observed data	NO	**15**	7	68.2
	YES	6	**88**	88.3
	Total correct	15+88 = 103		103/116 = 88.8

Table 22. Revised logit model. Goodness of fit (II)

Cox and Snell R square	Nagelkerke R square
0.411	0.657

4. Conclusions

From the above findings, we can sum up a series of policy relevant implications:

1) Firms' energy management factors are crucial to increase the likelihood to invest in energy efficiency.
2) We find evidence of path dependency concerning energy efficiency adoption behaviours in developing countries` firms. If policy actions are implemented to help firms in developing countries to invest today, they will more likely invest in energy efficiency in the future.
3) Microeconomic rather than external conditions are crucial to promote energy efficiency.
4) Top management commitment is identified as the most important business constraint reducing the likelihood to invest in energy efficiency.

Those findings let us conclude that policy makers should be engaged to enhance energy efficient projects in developing countries by actions that can affect the internal organization of firms rather than broad macroeconomic policies. Management innovation rather than the mere introduction of targets or indicators could represent the best tool to promote energy efficiency.

Even other relevant factors such as staff expertise and the existence of certification system programmes could be less effective in reducing energy efficiency, if firms do not organize procedures and methodologies to change radically the internal organization.

Policy will also be very important to remove microeconomic internal barriers such as the lack of capital that our findings show to decrease the likelihood to invest in energy efficient projects. A strong coordination between government, international organizations and firms will very important to reduce global warming.

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Appendix 1 Categorical explanatory variables in the logistic regression

UNIDO priority actions	**Explanatory variables**
Target setting	1) Does your company have an energy policy? (Y/N) 2) Does your company have energy performance indicators? (Y/N) 3) How important is energy consumption reduction in relation to all other issues your top management is considering at present? (Not important, somewhat important, very important, most important) 4) Energy efficiency barrier: Lack of external drivers such as mandatory energy efficiency targets or CO2 emissions targets (1 poor relevance – 4 high relevance) 5) Energy efficiency barrier: the market does not place any added value on energy efficiently performing companies
Capacity building	1) Does your company have awareness programs in place to encourage energy conservation and efficiency? (Y/N) 2) Energy efficiency barrier: there is insufficient technical expertise to identify, develop and implement energy efficiency (1 poor relevance – 4 high relevance) 3) Energy efficiency barrier: there is insufficient information on costs and benefits of energy efficient projects 1 poor relevance – 4 high relevance)
Energy management	1) Is your company considering or planning any energy management improvement action? (Y/N) 2) Does your company carry out energy audits? (Y/N) 3) Energy efficiency introduction barrier: top management is not committed to energy efficiency (1 poor relevance – 4 high relevance) 4) Were energy efficiency projects implemented in the last two years? (Y/N) 5) Energy efficiency barrier: Energy efficiency projects may interrupt production (1 poor relevance – 4 high relevance) 6) Top management is not committed to energy efficiency (1 poor relevance – 4 high relevance)
Certification	1) Is your company using a management system? (Y/N)
Policy	1) Energy efficiency barrier: Insufficient capital (1 poor relevance – 4 high relevance) 2) Energy efficiency barrier: Existing policies are inadequate to promote and support energy efficiency in industry (1 poor relevance – 4 high relevance)
Firms characteristics	**Explanatory variables**
Size	Number of employees
Country	Country

Appendix 2 Information on the dataset

Country	**Observations**	**Sector**	**Observations**
Viet Nam	110	Cement	14
Philippines	84	Chemical	29
Singapore	27	Food & beverage	97
Moldova	20	IT & electronics	10
		Others	17
		Paper	16
		Pharmaceutical	6
		Plastics	13
		Rubber	6
		Textile	21
Total	241		241

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