Profitability and energy efficiency: a firms' fixed effect approach

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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).

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 for running 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 having separate entries for the key variables in our analysis in each of those years. In this way 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 to tackle 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 maximise the number of observation given the data available.[1]

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 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 effect 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 Table A1 for a complete description of the variables used).

[1] 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.

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 (number of workers and value of the equipment) and time invariant (age, exporter status, foreign ownership and ISO certification) respectively, λ are industry effects and γ is time dummies.[2] 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 maximise 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:

[2] All the variables used in the regressions are described in Table A1 in the Appendix.

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

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 minimising 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.

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 8 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

[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.

sample size is vastly 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 reduce substantially or eliminate entirely 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, Vietnam), the beta coefficients are not much affected relative to column (2).

On the other hand results change substantially when adding firm's fixed effects in column (4). No beta coefficient is now positive, while for 21 countries they are negative and for 8 countries the coefficients are not significantly different from zero. 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 only for Mauritius the coefficient is significantly more negative after the inclusion of firms' effects. 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, Vietnam, 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.

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% of the firms in the dataset) have negative energy intensity coefficients, half of which are significant at least at the 10% 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.

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 characterised 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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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)	
Vietnam	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%. 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.*

Table 2: 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

*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.*

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
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

*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.*

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 minimise 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% 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
ElSalvador	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
SouthAfrica	1,809	1,251	1,143
SriLanka	1,356	1,025	0
Tanzania	828	425	306
Thailand	4,155	4,109	1,508
Uganda	900	414	0
Vietnam	3,450	3,135	2,852
Zambia	621	454	448

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