Macroeconometrics of the **G**lobal **E**conomy (MaGE)
Update on energy productivity

Jean Fouré

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We found out that the most recent data on energy consumption issued by the World Bank in World Development Indicators (WDI) were very different from the previous ones for certain countries (especially for Sub-saharan Africa countries), as well as it included new data points between 2008 and 2011. This update lead us to reconsider our approach on energy productivity, since the previous one was not valid anymore. However, we think that the determinants we isolated in our initial paper are still valid, and we tried to find a better specification that would fit the new dataset, as well as the previous one.

1 Framework

1.1 Definition of energy productivity

As documented in Fouré et al. (2013), we define energy productivity as the input-augmenting technical progress corresponding to the energy factor $E_{i,t}$ in our production function:

$$Y_{i,t} = \left[\left(A_{i,t} K_{i,t}^{\alpha} L_{i,t}^{1-\alpha} \right)^{\frac{\sigma-1}{\sigma}} + \left(B_{i,t} E_{i,t} \right)^{\frac{\sigma-1}{\sigma}} \right]^{\frac{\sigma}{\sigma-1}} \tag{1.1}$$

Under the assumption of a representative firm maximizing its profit under perfect competition, we show that energy productivity can be expressed as a function of GDP, energy consumption $E_{i,t}$ and the energy price $p_{E t}$ (which is assumed to equalize the oil price in our case):

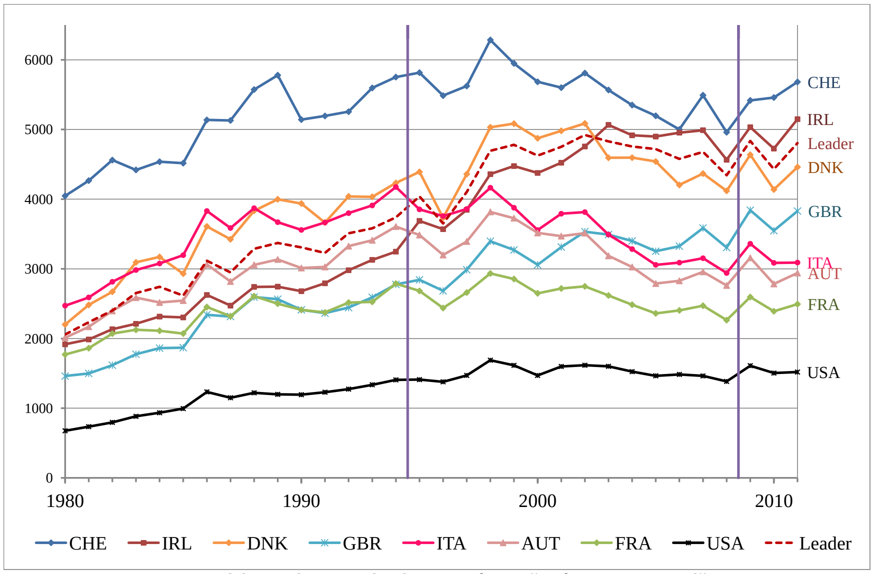
$$B_{i,t} = \left({p_{E}}_t^{\sigma} \frac{E_{i,t}}{Y_{i,t}} \right)^{\frac{1}{\sigma-1}} \tag{1.2}$$

This expression allows us to recover values of energy productivity over past data.

1.2 Leaders

As depicted in Figure 1, recent trends in energy productivity for the more efficient countries (especially during our reference period between 1995 and 2008) tend to favour Denmark and Ireland as leaders, contrary to our previous assumption (Denmark, United Kingdom, Japan, Germany and France), since the gap between those two groups is widening. We therefore changed our definition of the leader level accordingly.

Figure 1: Energy productivity for leader countries and the USA (constant 2005 USD per barrel of oil equivalent), 1980-2011



Vertical bars denote the limits of our "reference period".

1.3 Classification of countries

Regarding our previous specification, the estimation results were found not very robust with respect to the way we split the countries between OECD members and non-OECD members. Indeed, though simple, this distinction hides huge heterogeneity in terms of income level. Non-OECD countries can be classified both as high-, middle- or low-income – and therefore have a very agricultural or service-oriented economy – while Mexico and Turkey are OECD members but middle-income countries. To tackle this issue, we decided to rely on the world bank classification between income-level groups, which raised different issues: (i) the adaptation of our specification to this classification, and (ii) the rules for switching between different income categories.

2 Specification and estimation

We go further than previously in our ambition to have a single methodology for all countries over the world, by changing our specification.

2.1 The specification

Namely, rather than using separate estimations for the different groups (contrary to the savings-investment relationship, there is to our knowledge no evidence in the literature of an intrinsic heterogeneity), we introduce dummies for low-, middle- and high-income countries (respectively $\delta^L_{i,t}$, $\delta^M_{i,t}$ and $\delta^H_{i,t}$). See Section 3 for further detail on the definition of these groups. The δ dummies are interacted with GDP per capita relative to the United-States, such that we can still trace the effect of economic development (shift from agriculture to industry and lately to services) on energy productivity.

$$\Delta \ln B_{i,t} = \beta^0_i + \beta^1 \ln \frac{B_{i,t-1}}{\overline{B}_{t-1}} + \beta^2 \ln \frac{Y^{cap}_{i,t-1}}{\overline{Y}^{cap}_{t-1}} + \beta^3 \ln \frac{Y^{cap}_{i,t-1}}{\overline{Y}^{cap}_{t-1}} \times \delta^L_{i,t-1} + \beta^4 \ln \frac{Y^{cap}_{i,t-1}}{\overline{Y}^{cap}_{t-1}} \times \delta^M_{i,t-1} + \epsilon_{i,t} \tag{2.3}$$

If our intuition is valid, we should have the technological catch-up term $\beta^1 < 0$. In addition, we expect that $\beta^3 < 0$ (low-income countries shift from an agricultural-oriented economy to a more energy intensive industrial economy), as well as $\beta^2 > 0$ (with an increasing share of services). The sign of β^4 seems ambiguous, depending on le level of income per capita which would correspond to the minimum of the U-shape relationship we try to represent.

2.2 Country selection

We had as a constraint to have a set a countries that is compatible with the newest GTAP releases (8.2 and 9), despite the fact that data for the corresponding countries is sometimes hard to gather (e.g. for Rwanda or Equatorial Guinea), such that they do not appear (or for a very limited time span) in WDI energy consumption dataset. We therefore rely on U.S. Energy Information Administration (EIA) data, which include the countries we need, but for which energy consumption data can be very erratic (as Eguatorial Guinea). In addition, using two different datasets for a same measure introduces a bias due to the different methodologies used, making econometric estimations less reliable. Therefore, we exclude countries for which we use the U.S. EIA data from our sample. This corresponds to 40 countries.[1]

Finally, once we only retain countries for which we have WDI data, the variability in significance of the estimation (with different subsets of countries) is much reduced.

TABLE 1: ESTIMATION RESULTS

Dep. variable : $\Delta \ln B_{i,t}$	(1)	(2)
$\ln \frac{B_{i,t-1}}{B_{t-1}}$	-0.047***	-0.043***
	(0.007)	(0.006)
$\ln \frac{Y^{cap}_{i,t-1}}{Y^{cap}_{t-1}}$	0.026	
	(0.020)	
$\ln \frac{Y^{cap}_{i,t-1}}{Y^{cap}_{t-1}} \times \delta^L_{i,t-1}$	-0.029**	-0.009***
	(0.014)	(0.003)
$\ln \frac{Y^{cap}_{i,t-1}}{Y^{cap}_{t-1}} \times \delta^M_{i,t-1}$	-0.019	
	(0.014)	
Constant	-0.075***	-0.085***
	(0.025)	(0.013)
N	622	622
Groups	131	131
F-stat.	1.557	1.601
R-sq.	0.105	0.102

Standard errors in parentheses
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$
Source: authors' computations.

[1] Afghanistan, Burundi, Burkina Faso, Bahamas, Belize, Barbados, Bhutan, Central Africa, Cape Verde, Comoros, Djibouti, Fiji, Guinea, Gambia, Guinea Bissau, Equatorial Guinea, Guyana, Lao, Liberia, Santa Lucia, Lesotho, Macau, Madagascar, Maldives, Mali, Mauritania, Mauritius, Malawi, Niger, Papua New Guinea, Puerto Rico, Rwanda, Solomon Islands, Sierra Leone, Suriname, Swaziland, Tonga, Uganda, Saint Vincent and the Grenadines, Vanuatu.

2.3 Estimation

Equation 2.3 is estimated using fixed effects, such that the fixed effect β_i^0 captures all constant and unobservable country-specific characteristics. Results are displayed in Table 1.

Table 1 tends to corroborate our previous results, as well as the signs we expected. The main difference remains in the non-significance of the GDP per capita term for all countries and medium-income countries, suggesting that there is no distinction between medium-income and high-income countries regarding energy productivity.

3 Income groups

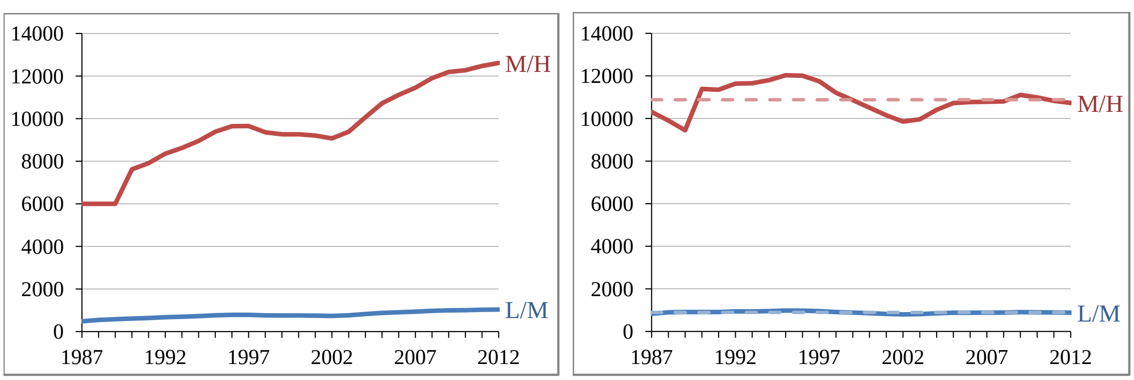
In previous version of MaGE, we used to rely on constant classifications (current income-level groups from the World Bank, or current OECD membership. However, at the horizons we consider (2050 or even 2100), it is very likely that countries will switch from one category to another. Therefore we tried to mimick the World Bank classification in a way that we could use dynamically (the δ dummies have t indices).

World Bank classification is build on a regular basis by setting GNI per capita thresholds (in current US dollars). We would however rather use GDP instead of GNI, and volume thresholds instead of current prices. To have insights in what we could do, we depict in Figure 2 the historical values of the thresholds published by the World Bank (Figure 2a), along with the same thresholds that we converted in constant 2005 USD (Figure 2b).

Figure 2b shows that the thresholds between income-level groups is roughly constant when corrected for inflation. We therefore compute the average GNI per capita threshold, at 894 constant 2005 USD for low/medium income and 10,883 constant 2005 USD for medium/high.

These thresholds are related to GNI per capita, whereas MaGE used GDP. The difference between the two lies in income obtained from and paid to foreign countries. However, these revenues are significantly important only for a few countries (like Luxemburg or Ireland). We therefore chose to neglect the difference between GNI and GDP per capita, setting out GDP per capita thresholds at the levels mentioned above and allocating countries accordingly. The outcome classification of countries is used both for regression and projections.

Figure 2: Income group thresholds (GNI per capita), 1987-2012



(a) Current dollars

(b) Constant dollars

"L/M" stands for the threshold between low- and middle-income, while "M/H" stands for the threshold between medium- and high-income. Plain lines are the actual threshold, dotted lines depict the average threshold.

References

Fouré, J., Bénassy-Quéré, A., and Fontagné, L. (2013). Modelling the world economy at the 2050 horizon. *Economics of Transition*, 21(4):617–654.