Energy Security and Diversity Index: Incorporating some policy dimensions

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Extended Abstract

Countries' energy policies aim to provide energy security (Kruyt et al. 2009; Winzer 2012). Countries achieve energy security, when they secure supplies, consume less, emit less pollutants (GHG), and diversify energy resources and import sources. To secure supplies, they acquire energy assets abroad, sign long-term contracts with energy providers, stock supplies, and safeguard onshore and offshore transport routes. To diversify energy sources, they reduce overall energy imports, often termed "energy independence", and encourage domestic exploration of existing and new resources. More importantly, however, they import from diverse sources instead of relying on few high risk suppliers. To diversify energy resources and reduce imports, countries shift away from expensive and/or environmentally harmful fossil fuels to relatively cheaper and/or more environment friendly resources like renewable, hydro, and nuclear energy.

The prices of energy products are also a policy instrument to achieve other goals of energy policy like diversification. Diversification of energy resources is one of the primary goals of energy policy. Traditionally coal and oil dominated the national energy baskets of all major energy consumers. The promise of nuclear and hydroelectricity in the 1960s brought about a shift of focus to these resources. The 1970s oil shocks further facilitated this shift. However, in the 1980s the risks of nuclear disasters and ecological consequences of large-scale dams became all too clear due to major accidents like the Chernobyl, Three Mile Island, and Banqiao (and recently Fukushima) accidents. The oil prices also came down in the 1980s due to reduced demand and ineffectiveness of OPEC in controlling oil prices (Colgan 2014; Mabro 1998).

Today, once again, governments across the world are focusing their efforts to move away from coal and oil towards gas, nuclear, hydro, and renewable technologies. This time around the high oil prices are not politically motivated supply shocks, but are the inflationary result of growing demand from Asian economies. The era of cheap oil is not only over, but the trend of rising prices seems irreversible (de Almeida and Silva 2011). Governments are also concerned about climate change, and coal and oil remain the largest sources of carbon emissions. Besides geographic and historical reasons, a particular country's national energy mix reflects the choices of successive governments to spread risk and balance the trade-offs between cheap and clean energy (for relative cost-benefit of different energy resources see Casten and Smith 2009; McCubbin and Sovacool 2011; Moniz 2011).

Therefore, the outcomes of policies aimed at diversifying energy resources would be reflected in the shift from one energy resource to another, irrespective of the policy instruments chosen to influence business and household decisions. There is no universal ideal energy mix that countries pursue. Depending on resource endowments, import dependence, level of economic development, and environmental commitments, we expect countries to be moving away from oil and coal to other resources; away from the oil mainly because of rising prices and the attendant political and economic risks of over dependence on imported oil in particular; away from coal because of growing environmental concerns, which we expect to be more pronounced in the developed countries as compared to the developing world.

Energy Diversity Index (coded as EDI) to capture the success or failure of the diversifying efforts by governments. I develop the index after the concept of Hirschman-Herfindahl-Index (HHI). The HHI is a measure of market concentration and is commonly used for the application of antitrust laws. The basic idea is that the higher the value of the index the more concentrated the market. It is calculated as follows:

$$\text{EDI} = \sum_{i=1}^{n} X_i^2 \quad (1)$$

Where X is the share of firm *i* in the market and n is the total number of firms. The value of EDI varies from 1/n to 1. In our case, I substitute firm with fuel type. The resultant index would indicate the level of diversification or concentration. For example if a country relies only on oil for all its needs, the EDI value is 1. Alternatively, if a country has four fuel types with an equal share in the national energy basket then the EDI value is 0.25. To further normalise this index so that the values fall between 0 and 1, I use the following normalizing function:

$$\text{EDI} = \frac{EDI - \frac{1}{n}}{1 - \frac{1}{n}} \quad (2)$$

The EDI is, however, sensitive to the definition of substitutability. In our formulation, the implicit assumption is that every country has four fuels (coal, oil, gas, others) and the fuels are perfectly substitutable in the long run. This assumption may be true for all fuels that are used for electricity generation. However, it may not be true for oil in the transport sector. The experience across the world shows that the transport sector has a limited number of choices other than oil, namely compressed natural gas or electricity. These choices of gas fuelled and electric vehicles, however, suffer from entry barriers, technological bottlenecks, and infrastructure problems. Nevertheless, relative successes in demand management and eliminating electricity generation from oil would reflect the diversification efforts. Since we are primarily concerned with shifts away from oil and coal, and the data on other fuel types is limited, I assume that there are a total of four fuel types, namely oil, gas, coal and others. The 'others' category would capture all hydro, nuclear and renewable resources.

The initial reading of the data suggests that there is a convergent pattern across the world in terms of diversification of energy inputs (Figure Error**! No text of specified style in document.**.1 and 3.6 below). This is particularly impressive for developing countries like China and India because there has been a manifold increase in urbanization, transport sector, and overall energy demand over the last two decades. Nevertheless, the IEA estimates suggest that coal use is on the rise and would continue this trajectory for some time to come, mainly in the developing countries. The table and graphs (Table Error**! No text of specified style in document.**.1 Figure Error**! No text of specified style in document.**.1) below show that all major economies have either reduced or halted the growth of their oil and coal use as a percent of total primary energy consumption.

The convergent trend is prevalent across the world (see Table Error**! No text of specified style in document.**.2 and

Figure Error**! No text of specified style in document.**.2 below). However, this trend is more prominent within OECD as compared to the non-OECD countries. The share of oil in national energy baskets across our sample has declined from 47 percent in 1995 to 40 percent in 2012. A decrease in standard deviation from 18 to 14 over the same period is indicative of a convergent pattern with a downward shifting mean. Similarly, while the share of coal has shown little change, the standard deviation has slightly decreased. This is partly explainable by the fact that many countries in the non-OECD group are resource rich net oil and gas exporters and often depend on one fuel type. However, as we discussed earlier in chapter 2, the rising oil and gas prices shall pose larger opportunity costs and these countries shall gradually diversify. We observe such a trend beginning to take shape at least since 2009. Similarly, the overall EDI value has declined from 0.25 in 1995 to 0.19 in 2012 with a concomitant decline in the variation from 0.16 to 0.15 over the same period. Nevertheless, the OECD countries have been more successful in diversifying their national energy mixes as compared to the non-OECD countries.

Table Error! No text of specified style in document.**.1: Top Six Energy Baskets (1990-2012) in mtoe (% share)**

Rank	Country	Oil	Gas	Coal	Nuclear	Hydro	others	World Share
3	China (1990)	116 (19)	14 (02)	465 (77)	-	10 (2)	-	(8)
1	China (2012)	452 (18)	122 (05)	1,866 (74)	21 (1)	59 (2)	6 (0)	(21)
1	USA (1990)	861 (43)	497 (25)	451 (23)	150 (8)	25 (1)	7 (0)	(25)
2	USA (2012)	961 (41)	627 (27)	463 (20)	206 (9)	28 (1)	40 (2)	(20)
2	EU (1990)	664 (44)	301 (20)	349 (23)	185 (12)	23 (2)	2 (0)	(14)
3	EU (2012)	694 (42)	443 (27)	205 (13)	224 (14)	26 (2)	42 (3)	(19)
4	Russia (1993)	190 (25)	411 (54)	111 (15)	30 (4)	15 (2)	-	(8)
4	Russia (2011)	138 (18)	465 (60)	114 (15)	42 (5)	14 (2)	-	(7)
6	India (1990)	59 (34)	12 (07)	95 (55)	1 (1)	6 (4)	-	(2)
5	India (2012)	174 (32)	59 (11)	297 (54)	8 (1)	11 (2)	2 (0)	(5)
5	Japan (1990)	269 (61)	54 (12)	61 (14)	50 (11)	8 (2)	1 (0)	(6)

6	Japan (2012)	226 (59)	106 (28)	-	40 (11)	7 (2)	3 (1)	(3)

Figure Error! No text of specified style in document.**.1: Top Six Energy Baskets (1990-2012) in mtoe (% share)**

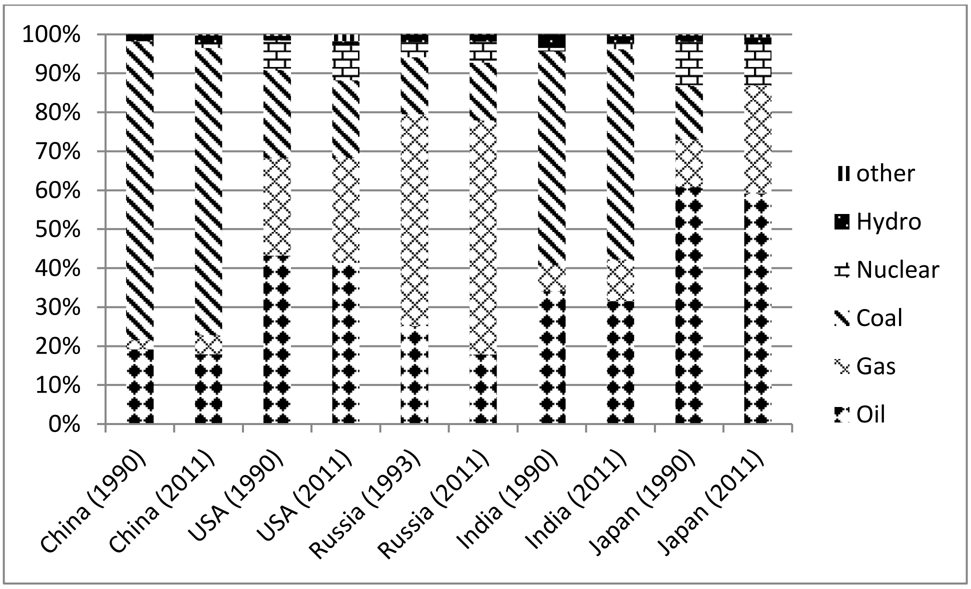


Table Error! No text of specified style in document.**.2: Oil and Coal Share, Mean and Variance (percent of total energy consumption)**

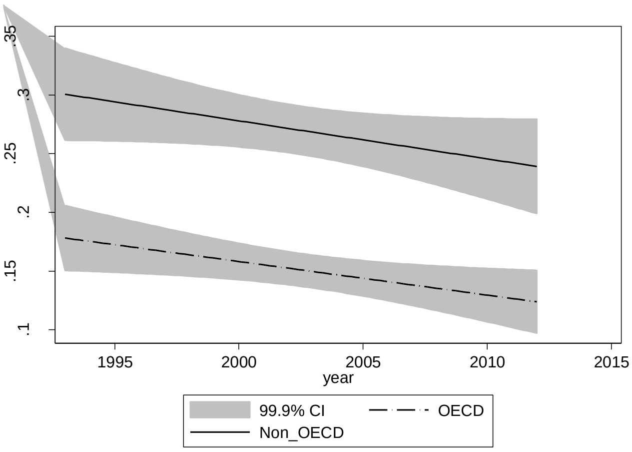
Oil	World	OECD	Non-OECD	Coal	World	OECD	Non-OECD
Mean				**Mean**			
1995	47	45	49	***1995***	16	16	16
2012	40	39	42	***2012***	16	15	16
Std. dev.				**Std. dev.**			
1995	18	13	20	***1995***	18	12	21
2012	14	09	17	***2012***	16	12	19
No. of countries	60 60	24 28	36 32	***No. of countries***	60 60	24 28	36 32

Source: BP/EIA.

Table Error! No text of specified style in document..**3: Energy Diversity Index**

EDI	World	OECD	Non-OECD
Mean			
1995	.25	.17	.30
2012	.19	.12	.25
Std. dev.			
1995	.16	.11	.17
2012	.15	.08	.17
No. of countries	60	24	36
	60	28	32

Figure Error! No text of specified style in document..**2: Energy Diversity Index**



Note: The line in the middle is the mean of the sample and the shaded area is confidence interval. The number of countries may not be same throught the years.