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A quantitative Analysis of Energy Security Performance by Brazil, Russia, India, China, and South Africa in 1990-2015

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ABSTRACT

The paper addresses the gap existing in the scholarship and provides an analysis of the energy security performance made by the group of Brazil, Russia, India, China, and South Africa (BRICS) over the total of 25 years, from 1990 to 2015. The research is based on a comprehensive approach to understanding energy security as the total of four dimensions: Availability, efficiency, affordability, and environmental stewardship. An energy security performance index operationalizes each dimension of energy security with three indicators, which allows to quantitatively measure the progress made by the group of BRICS in terms of ensuring their energy security. The research conducted surprisingly shows that the overall energy security of BRICS as a group of states has not changed over the years. However, each country has experienced considerable changes in energy security performance, with the most dramatic ones made by Russia (growth) and China (decline).

Keywords: Energy Security, Index, Brazil, Russia, India, China, and South Africa
JEL Classifications: Q2, Q3, Q4

1. INTRODUCTION

Brazil, Russia, India, China, and South Africa (BRICS) is a group of five rapidly emerging economies that include Brazil, Russia, India, China, and South Africa. The organization was founded in June 2006 as part of the St. Petersburg Economic Forum with the participation of the ministers of economy of Brazil, Russia, India, and China (South Africa joined later). Countries cover more than 25% of land and 40% of the world's population. In 2018, the group of BRICS had a combined nominal GDP of 18.6 trillion USD (23% of the world' nominal GDP), while their combined GDP (PPP) was around 40.55 trillion, comprising 32% of worlds GDP PPP (World Bank, 2018). In addition, the BRICS countries are rich with natural resources and have an impact on world markets. The first BRIC summit was held in June 2009 in Yekaterinburg. Since then, meetings have been held annually, alternately in member countries. One of the most discussed summit agendas is the issue of energy security (TASS, 2017). Our literature review clearly demonstrates that energy security of member countries is well reflected in the contemporary scholarship. Since China became the largest energy consumer in the world (citation), there has been published a great number of papers published on various aspects of China's energy security (Yao and Chang, 2014; Xingangn and Pingkuo, 2014; Zhang et al., 2017; Duana and Wang, 2018; Wang et al., 2018; Yao and Chang, 2014; Gholz et al., 2017; Wu, 2014; Yao and Chang, 2015; Cao and Bluth, 2013; Odgaard and Delman, 2014; Leung et al., 2014; Leung, 2011; Wu et al., 2012). India is also covered in the contemporary scholarship devoted to energy security extensively (Garg and Shukla, 2009; Pode, 2010; Jain, 2010; Kumar and Agarwala, 2013; Gunatilake et al., 2014; Narula et al., 2017; Rathore et al., 2019; Zhang et al., 2018; Narula et al., 2017). Brazil (Prado et al., 2016; Bradshaw and Jannuzzi, 2019), Russia

(Senderov and Edelev, 2017; Kaveshnikov, 2010; Seliverstov, 2009; Belyi, 2003; Bilgin, 2018; Blank, 2007; Vatansever, 2017; Smith, 2008), and South Africa's (Sebitosi, 2008; Gulati et al., 2013; Trollip et al., 2014; Winkler, 2007) energy security is also studied in numerous sources.

Surprisingly, despite a great number of separate studies on energy security of individual countries that are members of BRICS, common energy security of Brazil, Russia, India, China, and South Africa as a group of countries is not addresses in the scholarship at all. There is a number of studies devoted to energy related topics, but none of them conceptualizes or directly measures energy security of the group of BRICS. For instance, (Gu et al., 2018) review the BRICS group of countries' perspective on renewable energy as part of the general paradigm of human security. Focusing on African countries, they argue that the New Development Bank can ensure more effective renewable energy cooperation between BRICS and African countries. However, much more is to be done, especially in terms of developing a strategy for renewable cooperation both inside the group and with other countries. At the same time, the authors see China and India as the leading countries in transferring renewable energy technologies in Africa. In turn, (De Castro et al., 2016) state that energy is the driving force of world economy the demand on which is constantly increasing; therefore, the issue of ensuring the sustainable energy supply is the top priority., including in the BRICS countries. The authors consider increasing energy efficiency a necessary condition for all nations willing to develop their economies. The paper measures energy efficiency performance of the Group of Seven (G7) and the BRICS countries using the Tobit model. The research shows that BRICS countries significantly lag behind the G7, and their energy efficiency performance is very different from each other. Another scholar analyzes the "ecological indicators relevant to long-term sustainability by the food-energy-water nexus among BRICS" (Ozturk, 2015), while (Wilson, 2015) reviews the assumption that the economic growth in the BRICS countries was significantly backed by their richness in energy resources. There are also two studies that focus on the role of BRICS in global energy governance (Downie, 2015) and energy cooperation between them (Ryazanova, 2014).

Consequently, the purpose of the paper is to comprehensively evaluate energy security of the BRICS countries and fill the gap existing in the scholarship. Since there are no studies on energy security of this large group of states, this paper quantitatively evaluates the overall energy security performance made by BRICS countries over the quarter of a century. Because of the data (especially coming from the World Bank), our research covers 1990-2015. In order to quantitatively analyze energy security of the BRICS countries, we construct an energy security performance index that encompasses the following four dimensions: "availability," "affordability", "energy efficiency", and "environmental stewardship". Each dimension is operationalized using three indicators, i.e., the total of 12 indicators are used to measure energy security performance. We also would like to note that this research is a continuation of our series on energy security of Russia and other countries (Bogoviz et al., 2017; Bogoviz et al., 2018; Ragulina et al., 2019).

In the nest section of the paper we explain both the data and methods used to quantitively analyze energy security performance of the five emerging global economies. Then we proceed with results of our research and present our energy security performance index and discuss the results obtained. Lastly, we conclude with final observations and remarks.

2. DATA AND METHODOLOGY

Despite there is a lot of high-quality research on energy security published in recent years, the concept of "energy security" is still quite debatable (Manson et al., 2014), which leads to an array of approaches in the contemporary scholarship. Some scholars define energy security as merely the security of supply and market prices (IEA, 2001; Vera and Langlois, 2007), while other scholars attempt to expand the concept of energy security by including more perspectives, such as (a) energy surplus opportunities and energy scarcity situations (Blum and Legey, 2012), (b) an environmental component (Cao and Bluth, 2013), (c) climate change issues (Gracceva and Zenewski, 2014; King and Gulledge, 2014), (d) energy "acceptability" (Tongsopit et al., 2016; Yao and Chang, 2014).

Following the main goal of this research, which is to quantitatively evaluate energy security performance of the BRICS countries, we rely on the methodology developed by Brown et al. (2014), which was already used in our research on the Eurasian Economic Union (Bogoviz et al., 2017) and Russia (Ragulina et al., 2019). The undeniable advantage of this methodology is that it allows one to assess energy security using a fairly large number of quantitative indicators.

(Brown et al., 2014) use the following definition of energy security: "Equitably providing available, affordable, reliable, efficient, environmentally benign, proactively governed and socially acceptable energy services to end-users" (Brown et al., 2014). Consequently, there are four dimensions of energy security: (a) "availability" (diversity of the fuels and dependency on foreign suppliers); (b) "affordability" (reasonable price and low volatility); (c) energy "efficiency" (energy equipment and consumer behavior); and (d) "environmental stewardship" (the natural environment and future generations to be protected) (Sovacool and Brown, 2010). One may find more about each dimension in the aforementioned papers (Sovacool and Brown, 2010; Brown et al., 2014; Bogoviz et al., 2017; Ragulina et al., 2019).

We operationalize each dimension with three quantitative indicators, which allows us to construct a comprehensive ad measurable energy security performance index. To reflect energy "availability", we calculate each country's dependence on fuel imports, particularly on oil, natural gas, and coal. The data come from the IEA (2007). Also, we use the method developed by (Skinner, 1995) to calculate import dependence on each fuel. The "affordability" dimension is operationalized with the following indicators (World Bank, 2018): (a) access to electricity, % of population; (b) pump price for gasoline, US$/L; (c) pump price for diesel fuel, US$/L). The third dimension, energy "efficiency," is measured via the following proxies (World Bank, 2018): (a) renewable energy consumption, % of total; (b) GDP/unit of energ use, 2011 PPP $ per kg oil equivalent; (c) electric power consumption, kWh per capita. Lastly, the "environmental stewardship" dimension is measured by (a) CO_2 emissions per unit of GDP, kg CO_2/2010USD; (b) energy related methane emissions (% of total); (c) nitrous oxide emissions (thousand metric tons of CO_2 equivalent). The data for these indicators is also obtained from (World Bank, 2018).

The methods of z-scor normalization is applied to quantitatively measure the relative magnitudes of change in the indicators between 1990 and 2015. The comparison of such changes in z-scores allows one to see how energy security performance index has been changing over time.[1] We provide all the data collected and the calculations made in Tables A1-A8.

3. RESULTS AND DISCUSSION

The obtained data was analyzed according to the methodology and framework outlined above. Results of the z-score normalization are presented in Tables 1 and 2 and Figures 1 and 2. According to our index, back in 1990, only Brazil and South Africa had negative values of energy security performance index: −3.98 and −0.62, respectively. Other countries had close values of energy security performance, ranging from the lowest (1.13 by Russia) to the highest one (1.83 by China). Twenty five years later, Brazil had almost the same performance, growing by only 0.29 point (and still having the worst energy security performance among other BRICS countries). One of the largest energy producers in the world, Russia, significantly strengthened its energy security performance and grew by 4.57 points. In contrast, China only worsened its performance and fell by 4.88 points, which was the largest fall among all BRICS countries. India also decreased its energy security by 0.965 point according to our index. In turn, South Africa managed to grew by 0.97 points and moved from negative to positive energy security performance by 2015.

In our opinion, it is of particular interest to evaluate each country's energy security performance focusing on each dimension, because it would provide insights into energy security dynamics existing within the countries of BRICS.

A slight growth of the energy security performance index in Brazil was made due to its increase in the "availability" dimension by 1.31 points. Over 25 years, Brazil was able to decrease its import dependency on oil and coal, but its natural gas dependency grew significantly (by 120%). The largest decrease occurred in the "affordability" dimension – Brazil lost 1.05 points. Despite the growing access to electricity, Brazil experienced a significant growth in pump prices for both gasoline and diesel, which affected its scores on the energy "affordability" dimension. In addition, it is worth noting that other dimensions ("efficiency" and "environmental stewardship") experienced insignificant changes.

Russia is the only country that, according to our data, experienced growth in all dimensions of the energy security index, with the most significant changes in the "availability," "affordability," and "environmental stewardship" dimensions. In particular, the index for the "affordability" dimension grew by 3.42 points (which was the largest growth among all other countries and indices). More than that, the "availability" dimension also increased by 1.2 points mainly due to the increased ability of Russia to export coal (in 73 times) and keep almost the same negative values in oil and natural gas dependency. Also, Russia's "environmental stewardship" grew by 0.91 in large part because of much lower nitrous oxide emissions (160,717 in 1990 vs. 65,194 thousand metric tons of CO_2 equivalent in 2015).

According to the index, India is the country lowered its energy security performance in 205 by 0.94 if compared with the 1990 level. The country experienced the most significant decrease in the "availability" (-0.43) and "affordability" (-0.86) dimensions. A slight growth was made in the energy "efficiency" (0.4) and "environmental stewardship" dimensions (0.23).

In contrast to Russia's experience, China had all energy security dimensions decreased, with the most severe decrease in the "affordability" dimension (loosing 2.72 points) because of growing prices on gasoline and diesel fuel (in almost two times). "Environmental stewardship" is another dimension with a strong decrease (−1.12), which was affected by the growing greenhouse

1 Z-scores are calculated by subtracting the mean value out of each data point and then dividing it by the standard deviation of the whole indicator (Brown et al., 2014; Obadi and Korcek, 2017). The signs of the original z-scores are reversed in order to be consistent with the index (following Brown et al., 2014).

2. Positive differences in z-scores indicate better energy security.

Table 1: An aggregated energy security performance index for BRICS countries (total), z-score normalization results (with reversed signs), 1990-2015[2]

Country	Energy security performance index		Difference
	1990	2015	
Brazil	−3.98	−3.69	0.29
Russia	1.13	5.7	4.57
India	1.64	0.69	−0.95
China	1.83	−3.05	−4.88
South Africa	−0.62	0.35	0.97

Table 2: An aggregated energy security performance index for BRICS countries (dimensions), z-score normalization results (with reversed signs), 2015-1990

Country	Availability	Efficiency	Affordability	Stewardship	Total
Brazil	1.31	−0.17	−1.05	0.20	0.28
Russia	1.12	0.11	2.42	0.91	4.57
India	−0.43	0.11	−0.86	0.23	−0.94
China	−0.54	−0.49	−2.72	−1.12	−4.88
South Africa	−1.46	0.44	2.21	−0.22	0.97

Figure 1: Shifts in the aggregated energy security performance index made by BRICS countries, 1990-2015

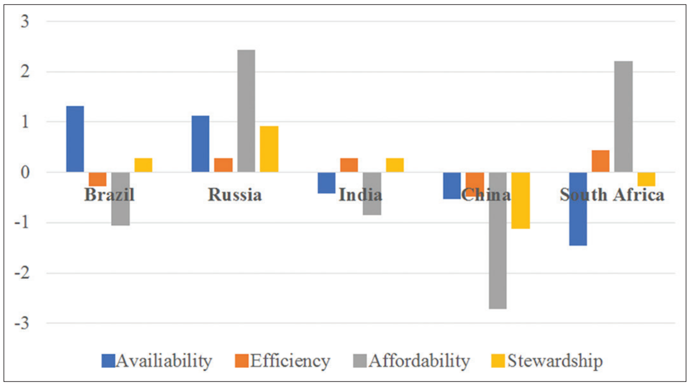
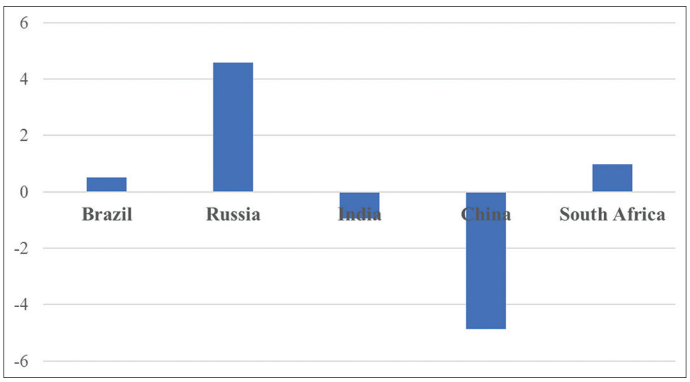


Figure 2: Shifts in the aggregated energy security performance index made by each country, 1990-2015



gases emissions. Energy "availability" also dropped because of China's increasing reliance on imported fossil fuels, namely on oil (3.8 times), coal (4.7 times), and natural gas (4.7 times). As an energy dependent country, such an increase only deepened country's fuel dependence. China's energy efficiency also decreased by 0.49, because its indicators on renewable energy consumption and GDP per unit of energy use had worsened over 25 years.

South Africa demonstrated a controversial behavior on the energy security performance index. On the one hand, it strengthened performance on the "energy affordability" dimension due to the growing access of the population to electricity (42%). Energy efficiency also grew by 0.44 point. The most significant decrease was due to the country's increased dependence on energy imports: 7.1% in oil and 191% in natural gas. It is worth noting that the coal export dependence even lowered because of the county's increased production and export of coal.

4. CONCLUSION

On the basis of the research conducted by us, the following conclusions can be made. First, the overall value of the energy security performance index has not change over 25 years, remaining at the same level despite all the changes each country experienced in the quarter of a century. This finding additionally demonstrates how different the BRICS countries are in terms of their economic development and dictates the necessity to comprehensively evaluate each country's energy security performance individually (including with qualitative methods).

Second, the most dramatic changes, according to the energy security performance index, have been experienced by Russia and China. Russia was able to increase its energy security by 4.57 points mainly because of excellent performance in the "availability" dimension, with respect to other BRICS countries, and moderate growth in the "affordability" and "environmental stewardship" dimensions. China demonstrated the worst fall on the energy security performance index (−4.88), with the lowering performance in all dimensions, especially in the "affordability" one. This result captures well the current status of Russia as one of the largest energy producers in the world. The same applies to China as the largest world's energy consumer.

Third, Brazil, India, and South Africa did not demonstrate any significant changes in their energy security performance. In particular, Brazil remained the country with the worst energy security performance score (−3.98 in 1990 and −3.69 in 2015), having the poorest performance in the energy "affordability" and "efficiency" dimensions but managing to grow by 0.29 point because of the constantly improving energy "availability" score. India, in turn, slightly decreased its energy security performance due to the worsening situation with energy "availability" and "affordability." South Africa managed to grow almost by one point, relying on better performance in the "affordability" and "efficiency" dimensions.

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APPENDIX

Table A1: "Availability" dimension indicators and z-scores (not reversed), 1990

Country	Oil import depend., %	Coal import depend., %	Natural gas import depend. %	Z-score: Oil import depend.	Z-score: Coal import depend.	Z-score: Natural gas import depend.	Total (not reversed)
Brazil	37.54158456	215.4852781	0	0.37201341	1.435257684	0.447213595	2.25448469
Russia	−191.0539884	−9.750703659	−101.507331	−1.630630695	−0.075195635	−1.788854382	−3.494680711
India	58.85768957	10.78656974	0	0.558756187	0.06252922	0.447213595	1.068499002
China	−29.82911558	−3.545543585	0	−0.218197213	−0.033583257	0.447213595	0.195433126
South Africa	99.87090528	−205.663955	0	0.91805831	−1.389008012	0.447213595	−0.023736107
Median	37.54158456	−3.545543585	0				
Mean	−4.922584907	1.462329119	−20.30146621				
St. Dev.	114.1468783	149.1181349	45.39545848				

Table A2: "Availability" dimension indicators and z-scores (not reversed), 2015

Country	Oil import depend., %	Coal import depend., %	Natural gas import depend., %	Z-score: Oil import depend.	Z-score: Coal import depend.	Z-score: Natural gas import depend.	Total (not reversed)
Brazil	−12.12789287	192.4183515	120.6194128	−0.473188369	0.882357	0.535567266	0.944735898
Russia	−119.7965092	−713.349474	−111.7071272	−1.538088677	−1.549544249	−1.530112297	−4.617745222
India	119.2907864	121.3522806	58.05237792	0.826612787	0.691551297	−0.020733556	1.497430528
China	84.21542607	13.22131444	43.8944535	0.479698679	0.401229844	−0.14661558	0.734312943
South Africa	106.9914319	−294.7312961	191.0622656	0.70496558	−0.425593893	1.161894166	1.441265854
Median	84.21542607	13.22131444	58.05237792				
Mean	35.71464843	−136.2177647	60.38427652				
St. Dev.	101.1067567	372.4525517	112.4697867				

Table A3: "Affordability" dimension indicators and z-scores (not reversed), 1990

Country	Access to electricity, % of population	Pump price for gasoline, US$/L	Pump price for diesel fuel, US$/L	Z-score: Access to electricity	Z-score: Pump price for gasoline	Z-score: Pump price for diesel fuel	Total (not reversed)
Brazil	87.5	0.53	0.38	0.479576992	0.655330686	0.410997468	1.545905146
Russia	98.4	0.35	0.28	0.939653494	−0.748949355	−0.410997468	−0.22029333
India	43.29	0.56	0.23	−1.386476415	0.88937736	−0.821994937	−1.319093992
China	92.2	0.27	0.24	0.677958603	−1.373073818	−0.739795443	−1.434910658
South Africa	59.3	0.52	0.52	−0.710712673	0.577315128	1.561790379	1.428392835
Median	87.5	0.52	0.28				
Mean	76.138	0.446	0.33				
St. Dev.	23.69171205	0.128179562	0.121655251				

Table A4: "Affordability" dimension indicators and z-scores (not reversed), 2015

Country	Access to electricity, % of population	Pump price for gasoline, US$/L	Pump price for diesel fuel, US$/L	Z-score: Access to electricity	Z-score: Pump price for gasoline	Z-score: Pump price for diesel fuel	Total (not reversed)
Brazil	100	1.02	0.95	0.730240842	0.741857604	1.129558023	2.601656469
Russia	100	0.59	0.55	0.730240842	−1.750320284	−1.625461546	−2.645540987
India	84.5	0.97	0.81	−1.077863479	0.452069477	0.165301174	−0.460492828
China	100	0.96	0.81	0.730240842	0.394111852	0.165301174	1.289653868
South Africa	84.2	0.92	0.81	−1.112859047	0.162281351	0.165301174	−0.785276522
Median	100	0.96	0.81				
Mean	93.74	0.892	0.786				
St. Dev.	8.572514217	0.17253985	0.145189531				

Table A5: "Energy and economic efficiency" dimension indicators and z-scores (not reversed), 1990

Country	Renewable energy consumption, % of total	GDP/unit of energy use, 2011 PPP $ per kg oil equitv	Electric power consumption, kWh per capita	Z-score: Renewable energy consumption, % of total	Z-score: GDP/unit of energy use, 2011 PPP $ per kg oil equitv	Z-score: Electric power consumption, kWh per capita	Total (not reversed)
Brazil	49.865	11.02	1457	0.75977475	1.699790369	−0.421503124	2.038061995
Russia	3.752	3.481	6673	−1.269080689	−0.464127158	1.480365642	−0.252842205
India	58.653	5.00	273	1.146424536	−0.029564068	−0.853215665	0.263644803
China	34.084	1.99	510	0.06545064	−0.892088563	−0.766800233	−1.593438155
South Africa	16.628	4.004	4152	−0.702569236	−0.314010582	0.56115338	−0.455426438
Median	34.084	4.004	1457				
Mean	32.5964	5.098	2613				
St. Dev.	22.72857845	3.483959027	2742.565678				

Table A6: "Energy and economic efficiency" dimension indicators and z-scores (not reversed), 2015

Country	Renewable energy consumption, % of total	GDP/unit of energy use, 2011 PPP $ per kg oil equitv	Electric power consumption, kWh per capita	Z-score: Renewable energy consumption, % of total	Z-score: GDP/unit of energy use, 2011 PPP $ per kg oil equitv	Z-score: Electric power consumption, kWh per capita	Total (not reversed)
Brazil	43.79	10.354	2601	1.261810056	1.427765592	−0.479715752	2.209859896
Russia	3.304	5.196	6602	−1.141722479	−0.610093427	1.39171826	−0.360097647
India	36.021	8.45	805	0.800587799	0.674729669	−1.319779607	0.155537862
China	12.413	5.107	3927	−0.600948437	−0.645256175	0.140509567	−1.105695045
South Africa	17.15	4.596	4198	−0.319726938	−0.847145659	0.267267532	−0.899605065
Median	17.15	5.196	3927				
Mean	22.5356	6.7402	3626.6				
St. Dev.	16.84437361	2.53108775	2137.932716				

Table A7: "Environmental stewardship" indicators and z-scores (not reversed), 1990

Country	CO_2 emissions per unit of GDP, kg CO_2/2010USD	Energy related methane emissions (% of total)	Nitrous oxide emissions (thousand metric tons of CO_2 equivalent)	Z-score: CO_2 emissions per unit of GDP, kg CO_2/2010USD	Z-score: Energy related methane emissions (% of total)	Z-score: Nitrous oxide emissions (thousand metric tons of CO_2 equivalent)	Total (not reversed)
Brazil	1.40	7.834	156824	−0.685211496	−1.057845996	−0.117578267	−1.860635759
Russia	13.98	67.692	160717	1.515167755	1.405145105	−0.083086587	2.837226274
India	0.712	13.103	169598	−0.80536574	−0.841041223	−0.00440161	−1.650808573
China	2.15	34.765	340451	−0.553514049	0.050290149	1.509342826	1.006118925
South Africa	8.341	44.32	22884	0.52892353	0.443451965	−1.304276363	−0.331900868
Median	2.152	34.765	160717				
Mean	5.3168	33.5428	170094.8				
St. Dev.	5.717650715	24.30297047	112867.7972				

Table A8: "Environmental stewardship" indicators and z-scores (not reversed), 2015

Country	CO_2 emissions per unit of GDP, kg CO_2/2010USD	Energy related methane emissions (% of total)	Nitrous oxide emissions (thousand metric tons of CO_2 equivalent)	Z-score: CO_2 emissions per unit of GDP, kg CO_2/2010USD	Z-score: Energy related methane emissions (% of total)	Z-score: Nitrous oxide emissions (thousand metric tons of CO_2 equivalent)	Total (not reversed)
Brazil	2.59	9.82	214529	−0.918017111	−1.095077606	−0.049500569	−2.062595286
Russia	11.858	79.509	65194	1.236550815	1.405933854	−0.719724472	1.922760197
India	1.73	17.207	239755	−1.11896127	−0.829971611	0.063715142	−1.88521774
China	7.54	48.033	587166	0.233225466	0.276317462	1.622915304	2.132458232
South Africa	8.98	47.099	21148	0.5672021	0.242797901	−0.917405404	−0.107405403
Median	7.544	47.099	214529				
Mean	6.5412	40.3336	225558.4				
St. Dev.	4.29970199	27.86432654	222813.5992				